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CONTENTS

EDITORIAL

For some time the Editorial Board has been considering possible improvements to the Journal, changes which would result in a publication more in keeping with modern ideas of presentation and at the same time, one which would provide a medium with which to strengthen the link between members of the Royal Naval Scientific Service.

The opinion of the Board has now been endorsed by the Senior Council who have asked that certain moderate changes be made. In this issue our regular readers will, no doubt notice, and we hope approve, certain modifications to style and in future issues we trust that the changes in accent and policy will also become apparent.

Whilst changes in policy and style are in the hands of the Board and the Editor, changes in content can only be made through the continuing support and co-operation of members of the R.N.S.S. themselves and their colleagues throughout the U.K. and the Commonwealth.

In future we hope to be in a position to publish more articles of general interest, topical leaders, profiles of personalities and short state of the art surveys, in addition to the current specialist articles.

We should like to express our gratitude to the many contributors over the past 25 years and, whilst inviting the continued support of those still with the Service, extend a further invitation to the younger, budding authors, who, so far, we have been unable to contact.

RESOURCE DEPLOYMENT

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Dr. Ralph Benjamin joined ASE (now ASWE) in 1944 from Imperial College. He has contributed to a wide range of that establishment's activities and published well over 200 technical reports. However his main field was air defence and aircraft control radar, action information systems, automation systems, and computers. He was made a special-merit SPSO in 1955 and a special-merit DCSO in 1960.

When a Deputy Chief Scientist and Head of Research at ASWE he wrote a book on Resolution Modulation on Signal Processing which gained him his doctor's degree from London University.

In 1964 he was appointed Head of AUWE. He has recently qualified as an RN diver.

Abstract

This article examines the problem of matching a time-varying spectrum of men, of assorted skill, seniority, etc., against a spectrum of specialised posts, arising from an uncertain, time-varying "order book" of tasks of assorted urgency and value.

A strategy of "maximum flexibility" is put forward for dealing with this situation.

The decision criteria involved are analysed into quasi independent basic constituents, which can be readily quantified by subjective judgement. Fairly simple systematic algorithmic procedures are then proposed, to derive from these basic inputs a reasonable approximation to an optimum deployment pattern, for final "editing" by managerial judgement. The same procedures are applicable to other problems of resource deployment.

A. Introduction.

1. Almost any non-trivial resource deployment task ultimately depends on human judgement for the assessment of the relative priority of various tasks and obligations, the relative desirability of alternative outcomes, the probabilities of certain events, the worth-whileness of different objectives, etc. This vital role of human judgement applies a fortiori to decisions involving human beings. The situation however does not rule out any scope for the definition of broad strategic aims or the formulation of *some* of the decision criteria involved; or indeed for some generalisation of the tactics of combining these criteria in the attempt to derive systematic procedures for their application.

2. It must however be recognised that, as applied to human resources, this is no recipe for substituting a remote, impersonal clerical or computer process for personal contact, human understanding and professional insight. This article is solely an academic exercise, which may help to clear the mind and so, possibly, help to reach equally good decisions more rapidly. In addition, it may assist in memorising or recording some of the considerations, which led to a given pattern of decisions, in such a form that less of the same ground has to be covered again if conditions change.

B. Considerations Affecting Deployment Decisions

1. Normally the tasks to be tackled differ quite widely:—
   (a) in magnitude
   (b) in essentiality
   (c) in urgency
   (d) in profitability
   (e) in the type of specialised skill called for.

2. Similarly, the men available to man the given programme of work differ widely in:—
   (a) their professional skills and training
   (b) their managerial abilities
   (c) their interactive personal qualities of leadership, co-operativeness, compatibility, etc.
   (d) their individual personal energy and drive
   (e) their status in the hierarchy of the organisation.

3. Our initial approach might be to split each project into a number of tasks and aggregate or sub-divide these as necessary to define a number of posts. These could then be listed

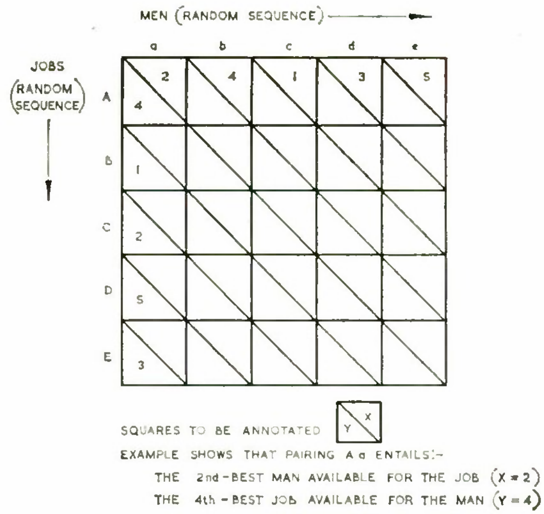


FIG. 1. Random Matrix.

vertically, one below the next, along the side of a piece of squared paper. See Fig. 1. The available men could then be listed side-by-side, horizontally along the top of the paper. Each square on this paper will then define the association of one man with one post. Along each row the $\hat{X}$ men could then be annotated in the appropriate sequence, from 1 to X, to indicate their relative suitability for the given post. Similarly, down each column, the $\hat{Y}$ posts could be marked in appropriate sequence, from 1 to $\hat{Y}$, in order of their appropriateness to the given man.

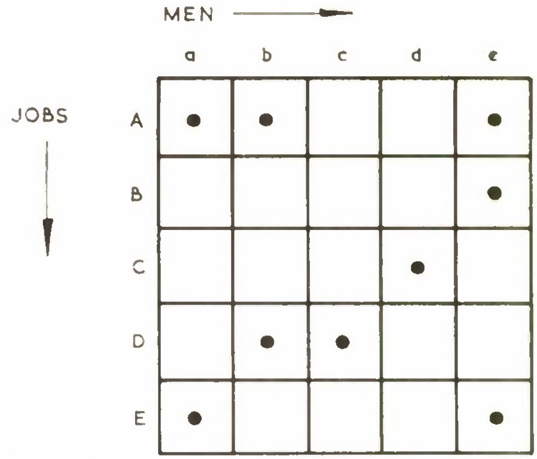
4. The effectiveness of a given assignment is then a negative function of both X and Y, *i.e.* the smaller X, the closer are we to the best man for this specific job, and the smaller Y, the closer are we to the most suitable job for the man. However, the *value* of the assignment depends also on the nature of the job itself, according to criteria (a) to (d) in paragraph B1, and on the actual effectiveness of the man on the job, according to criteria (a) to (e) of paragraph B2. The cost of the assignment depends also on the pay of the man and, more significantly, on his potential value to all other jobs—for which he would now no longer be available.

C. The Intractable Nature of the Deployment Matrix

1. For the moment, we shall disregard the possibility that there may be posts which *no*

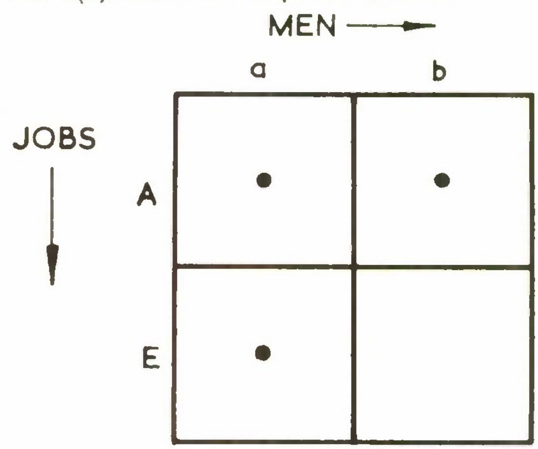
available man can fill, or men who are not satisfactorily employable on any available job, or that certain deployment decisions may make it unavoidable or desirable to create such a situation. However, where manning is difficult, it may well arise that a post is *essential* to a job which itself needs to be done, and only one man can do it. This post/man pairing can then be decided independently of the rest, and the corresponding row and column can be deleted in the matrix. Similarly, if a man is to be retained on the payroll, and he is satisfactory for *only one* of the posts currently available, another pairing is independently defined, and another row and column can be deleted. These deletions may then create other unique solutions in their turn. See Fig. 2. However otherwise, even where a pairing represents concurrently the best of several possible men for the job (*i.e.* minimum X in the row) and the best of several possible jobs for the man (minimum Y in the column), the pairing may not be optimum: the man might be more profitably employed on a more important job (or one more difficult to man up), or the job might be adequately, but more economically, filled with a less valuable man. Similarly, the *only* man capable of doing a desirable job might still be better employed as the best man to do a vital job. Or else the desirable job might fall through, *e.g.* because other parts of the relevant project cannot be adequately supported.

2. Thus the theoretical " optimum " solution to such a matrix is far from simple. Assuming we could assign suitable empirical values to the various parameters, and develop suitable arbitrary but plausible functions connecting them, it should nevertheless be possible to derive a " rigorous " solution to the optimisation problem—given sufficient patience or computer power. However, if a matrix has $\hat{Y}$ rows by $\hat{X}$ columns, each of $\hat{X}$ assignments in the first row can be associated with any of $(\hat{X} - 1)$ in the second, any of $(\hat{X} - 2)$ in the third, etc. Hence there are $\hat{X}! \;/\; (\hat{X} - \hat{Y})!$ potential solutions to be considered, each comprising $\hat{Y}$ assignments (assuming there are more men than posts). For many practical resource-allocation problems, this would be beyond the power of any existing or foreseen computer system, unless the problem can be broken down into smaller, quasi-independent constituent matrices or otherwise simplified.



Dots mark acceptable man/job pairings.
Cd is a unique solution for both C and d.
Be is a unique solution for B
Dc is a unique solution for c.

FIG. 2(a). Matrix of Acceptable Solutions.



Ab is a unique solution for b.
Ea is a unique solution for E.
Either assignment would leave the other as the only surviving pairing.

FIG. 2(b). Residue after Unique Assignments arising from Fig. 2(a).

3. In any case, the validity and value of the resultant solution would be vitiated not only by the subjective empiricism of the parameter values and functional relationships, but also by the static and determinate description of a situation that is dynamic and only incompletely knowable:— Tasks turn out to be harder—or easier—than expected, or indeed different in kind; delivery failures or equipment

breakdown cause delays; key men fall sick or resign—or new ones are recruited—major unexpected snags arise; important new tasks or valuable new opportunities appear, etc.

D. A Proposed Strategy of Resource Allocation

1. Rather than aiming at a " once-for-all " optimisation, we therefore formulate the principle that we wish to meet the known commitments, in an appropriate order of priority, in such a manner as to retain maximum flexibility to cope with new tasks, problems or opportunities. We may couple this with the assumption that any change of task is associated with a penalty for hand-over, learning and "acclimatisation" (and possibly interference with career planning). In other words, we must try to ensure that the tasks of the highest urgency, greatest importance, largest value, or longest duration are manned up to a fully adequate standard, but we must seek to meet these known priority commitments with minimum prejudice to our freedom to deploy powerful and flexible resources in support of further difficulties, tasks or opportunities that may arise.

2. Within this framework, we would wish to give priority to manning those jobs—and employing those men—which might otherwise pose difficult deployment problems.

3. Whilst pursuing these—possibly slightly startling—objectives, we must of course avoid having our most able and versatile personnel standing idle. Our aim is not to create an *uncommitted* reserve, but to create a *readily deployable* reserve. Hence we would endeavour to have these men fully and profitably occupied but, as far as possible, engaged on jobs of short duration, or limited immediate urgency, or self-initiated speculative ventures of high potential profitability, or similar activities from which they could be fairly readily withdrawn—or replaced by a staff of lesser calibre or versatility—if their services were urgently needed elsewhere.

4. Thus we now have a basis to define algorithmic procedures for constructing—and solving—the deployment matrix to satisfy the criteria above.

E. Scales of Job " Priority " and " Inflexibility " and of Personal " Worth "

1. First we must arrange the tasks to be done in order of overall priority. This is bound to be a largely subjective judgement and, where it is difficult to make up one's mind on the relative order of priority of two jobs, the choice made is *ipso facto* unlikely to be important. However, it clearly helps to list the principal considerations which affect the choice. Indeed it would be a helpful formalisation of, and guide to the judgement, if the contributing factors could be quantified, and combined in a suitable manner to produce a single scale. However, these values would be used largely to help in deriving the ordinal numbers defining the relative position of the tasks on the priority " league table ". Indeed the resulting league table would still be subject to amendment by subjective judgement

(a) when first compiled

(b) in the light of later experience or indeed hindsight.

However, the aggregate of such adjustments should be used to modify the weighting factors or otherwise revise the formal procedure outlined below, to reduce the need for such modifications in the future. It must however be re-emphasised that, where the relative priority is arguable, it generally also doesn't matter.

2. On the foregoing basis, it is proposed to assign to each task a composite

priority P, compounded of
the urgency U,
importance I,
value V,
and cost effectiveness C.

Although there is a degree of mutual reinforcement between these quantities, it may be adequate to combine them linearly. Thus (expressing each on, say, a subjective 5-point scale, increasing in unit steps from 1 to 5).

$$P = uU + iI + vV + cC$$

where u, i, v and c are empirical weighting factors, chosen to match sample jobs to experience-based subjective judgements of relative priority.

3. (Note that a job is " urgent " if it must be done quickly to be worth doing at all; but this need not imply it is important that it be done. Similarly, a job can be " important ", by virtue of being an inescapable commitment or, say, for reason of policy, or even prestige, without necessarily being valuable in the sense of being particularly profitable. Finally, a job can be " profitable ", by virtue of its sheer magnitude, although it requires a heavy commitment of scarce human, capital or financial resources—and so it may not be very cost-effective).

4. The likely *duration* of the job, D, is a quantity of a different kind, and indeed a prolonged commitment of scarce resources would diminish the net value V, and the cost-effectiveness C, in the formula above—as would also the magnitude of the resources to be committed over this period. However D, the duration of the job, like its priority P, contribute also to the *rigidity R, i.e.,* to the lack of freedom to redeploy the resources so committed. Hence we get a similar formula:—

$$R = P + dD.$$

(The inclusion of a separate weighting factor d, for D, could have been avoided. However it simplifies adjustment of relative weights).

5. We have now derived a single scale on which to arrange the jobs to be done in a useful and reasonably meaningful sequence. Let us now attempt to do the same with regard to the skilled men (or other specialised resources). The relevant parameters might be:—

the intrinsic quality	Q,
the specialised skill or training	T,
the versatility or flexibility	F,
the scarcity value (of unique qualifications)	S,
the administrative skills	A,
and personal or general qualities*	G.

On the same basis as before, we would assign empirical weighting factors to all these parameters and adjust them so that the resultant ordinal assessment of relative *total " worth " W* tallies with the pragmatic subjective judgement, where this can be checked. Thus we get:—

$$W = qQ + tT + fF + sS + aA + gG.$$

F. A Rationalised Matrix

1. We can now re-form our matrix, but now list the $\hat{Y}$ posts down the left hand edge of the matrix in order of *de*creasing rigidity R of the associated jobs, and list the men from left to right along the top of the paper in order of *in*creasing " worth " W. Thus, much relevant information will be conveyed by the *position* of a square (denoting a possible man-to-post pairing) on the matrix. In addition, however, we still require to know the suitability, with regard to the men and jobs, of the potential pairings. This we now propose to define as:

x, the suitability of the man for the job, and

y, the suitability of the job for the man,

each assessed on a five-point scale increasing in unit steps from 0 to 4. See Fig. 3.

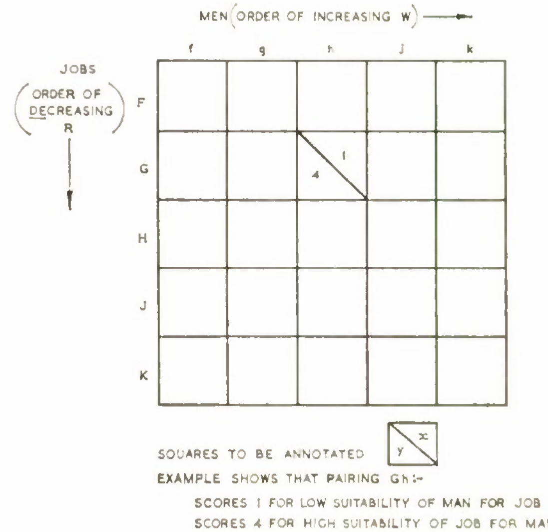


FIG. 3. Ordered Matrix.

2. Clearly, we would wish to associate with each square a single number, which defines the quality *of the pairing,* irrespectively of the R-value of the associated job (row) or the W of the man (column). This quantity must then be such a function of x and y that any total unsuitability of the job for the man—or the man for the job—cannot be masked (or " compensated for ") by an admirable match in the other dimension:— a man might be very seriously misused on a job, though he is the best man for it and could do it " standing on his head ". Conversely, a job might offer both full and unsurpassed scope for the exercise of a man's talents whilst the man is nevertheless totally inadequate for the job. Hence it is proposed to define the *pairing effectiveness* e as a multiplicative function of x and y. Since, however, failure in a commitment is likely to be more serious for all concerned than misemployment of talent, we want to include independent weighting factors m and n, such that:

$$e^{m+n} = x^{m} y^{m}.$$

3. Whilst the asignment of x and y (and hence e) values must ultimately be a matter of subjective judgement, an element of pre-

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* *Personal relations and compatibilities between individuals may be an important consideration in many of the assignments finally made. It is assumed here that this is one of the functions covered by human editing of the output from the systematic algorithmic procedure. The value of G will however reflect, in part, whether a man is likely to pose a difficult problem, in this respect.*

selection—and particularly rejection or tentative allocation of zero rating—should be possible by profile matching:— If a man's skills, qualifications, calibre and seniority are vastly in excess of a job specification, a low y will apply, though the x *may* be high. If the job gives full and realistic scope to the man's skills and qualities but demands additional qualities not possessed by the "candidate", y can be high though x is low. If the job demands skills totally different in kind, or is mismatched in quality both well above and well below that possessed by the man, both x and y are low. Thus with suitably standardised formulations of personnel and job profiles, systematic algorithmic procedures may also have a part to play in the preliminary assessment of individual man/job pairings.

G. No-Choice Assignments to Priority Jobs

1. Now at last we are ready to define our algorithmic procedures:— To begin with, we concentrate on a limited *band*, comprising the posts in the topmost rows (those of the highest priority and/or longest duration, i.e. greatest "rigidity" R), and assign the appropriate x and e values to all the men available. See Fig. 4. If any of these jobs are not matched by *any* suitable man, two alternatives arise:—

(a) Action is taken to recruit a suitable man, or to cover the work in some other manner—or to handle the specific aspect of the project by sub-contract; the given job-row is then deleted, as requiring no further consideration in our context:

(b) No alternative action to do the job is found to be possible—or desirable. Hence the relevant project must be cancelled and *all* job-rows attributable specifically to this project must be deleted from the matrix.

2. If a number of related jobs or posts are jointly essential to the fulfilment of a task, they would clearly be grouped together on the Y axis. It would probably be convenient to include them all in the active "band" at the same time. In any case, no firm personnel assignment to *any* of them can be made until it is confirmed that *all* the constituent jobs can be handled by the personnel available or by sub-contract with other organisations.

3. Note how the assignment matrix and procedure may be used as a tool to identify tasks to be covered by sub-contract. Alternatively, potential subcontractors might have been included in the personnel list, with their capabilities, and with appropriate weighting of the relevant primary parameters to indicate any financial or policy considerations affecting the employment of these organisations.

4. Having covered all instances of *no* direct solution, we can now shift our attention to those having a *single*, unique solution:— If only one man proves suitable for a job in the band, he is assigned to it (unless this represents an unacceptable misuse of the man, in which case we are back to the situation of paragraph G1). If a man is so assigned, both the job (row) and the man (column) are bespoken for, and hence are deleted from further consideration. The deletion of this man might reduce another row in the band to a unique solution, to be handled in the same manner, as discussed in paragraph C1 and illustrated in Fig. 2. Indeed, if one man is the only one suitable for two or more jobs within the band, the pairing assignment will produce another unfillable vacancy to be dealt with again according to paragraph GI above.

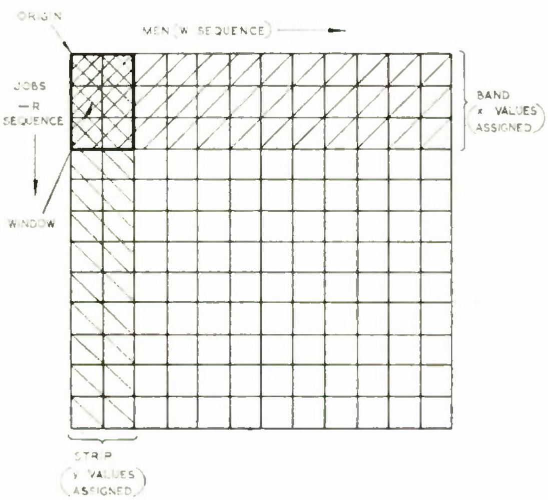

FIG. 4. Regional Selective Assignments.

H. No-Choice Assignments to Men "Difficult-to-Place"

1. At this point we would have dealt with the most difficult assignments amongst the "band" of jobs we most urgently wish to cover. We might therefore now concentrate on a narrow vertical *strip*, containing the left-hand most columns, i.e. those associated with men of low W rating, whom we wish to commit first, and we therefore assess the relevant y and

e values. The procedure is now closely analogous to that for the horizontal band.

2. First we look for any men, within this strip, for whom there is *no* suitable job whatsoever. Clearly we must either create suitable jobs (or indeed seek suitable orders) for them or else move them out of the department. In either case they are omitted from further consideration in our present context, and the relevant columns are deleted from the matrix. We then search for men, in the left hand strip, who would be suited *by* only one job. If they are not acceptably well matched to the job, from the point of view of both the man and the job, they are treated as " unemployable within the present order-book ", as above. Otherwise the assignment is made and the appropriate column (and row) deleted from the matrix.

3. If the deletion of the row creates another unique match to a man in the strip, the process is repeated, and if it deletes the only possible job for another man, within the left-hand strip, we have to cope with another unemployable, as above. Finally we must check whether the deletion of men has removed potential pairings within the top left-hand " window ", common to the band and strip, which cause new unique solutions or even unfillable vacancies to appear in the band, to be handled in accordance with paragraphs G1 and G4 above.

J. The Search for " Good " Assignments

1. Having noted the embarrassment caused by a lack of choice, and the danger of assignments elsewhere creating a " no-choice " or even " no-solution " situation, we shall next concentrate on jobs and men vulnerable to this. Hence we seek out jobs within the top " band " for which only two available men are suitable. This time however we have a choice, and so we might select the solution of the higher e-value. However, we might prefer to choose the one more to the left (*i.e.* of lower W), in accordance with our strategy of minimising the commitment of highly versatile staff. Clearly therefore we must suitably combine these two criteria, as discussed below.

2. Evidently, a totally unsuitable man/job pairing can never be made acceptable by the mere fact that the job and/or man are ones which we are particularly keen to assign as soon as possible. Hence it is suggested that these factors be combined in a multiplicative form, to define the *benefit B* as:

$B = e/W'$ in the " band ", outside the window.

$B = e/R'$ in the " strip ", outside the window, and

$B = e$ inside the " window " common to band and strip.

Here W' is the *ratio* of the man's W value to that at the right-hand edge of the window, and

R' is the ratio of $(\hat{R} - R)$ of the given job to $(\hat{R} - R)$ at the lower edge of the window.

where $\hat{R}$ is the maximum value of the rigidity figure R, and the subtraction arises because we wish to allocate jobs in order of *de*creasing R.

(since we merely wish to *compare* " benefit " figures, any monotonic function of B will serve, and so the comparisons may be made on the basis of log B, if desired. Any weighting indices found desirable for e, W' or R', then become weighting *factors* for log e, log W' and log R').

3. Thus, where there are two solutions to a job in the " band ", we choose the one of higher B—and then check whether this deployment has created any new unique solutions, to be dealt with as before. Next, we deal similarly with men, in the strip, for whom there are two possible (and suitable) jobs. Next we repeat the analogous process, in the band and strip, with regard to triple-choice situations.

4. Thereafter, it would probably suffice to take the remaining jobs in the band in turn, from the top downwards, and make to each the maximum-B assignment, and then to take the remaining men in the strip similarly from left to right (checking at each stage whether a triple-choice situation has been created which would then be handled as above). Having thus cleared the initial band and strip, we would reconstitute them with the next jobs and men, on the $-R$ and W scales, and then repeat the procedures of sections G, H and J above.

5. The ideal " space weighting " of each square on the matrix would probably be in inverse ratio to its spacings from *both* the W and R axes (assuming row and column positions represent the true *cardinal* number values of these quantities). This would result in hyperbolic space weighting contours, as illustrated in Fig. 5. Since the procedures proposed compare solutions solely along one row or column at a time, this two-dimensional weighting (whilst admittedly quite easy to apply) would have *no*

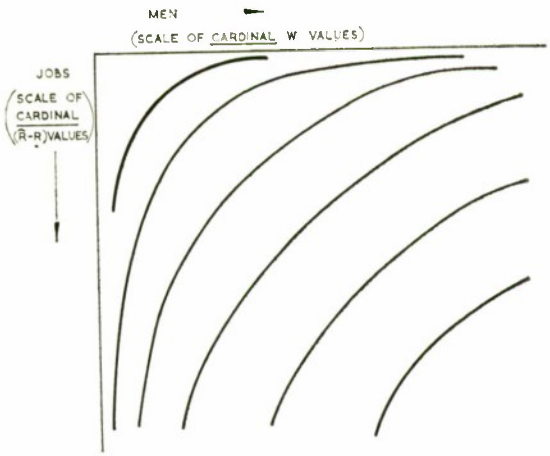

FIG. 5. " Ideal " zones of equal " Space " weighting.

effect on the result, except in respect of solutions within the top-left " window ". The " ideal " hyperbolic solution would, in this region, be unduly sensitive to small variations in R′ and W′. If a refinement within the window were thought justified, say to choose between otherwise equal solutions, it would no doubt suffice—and be safer—merely to give preference to the one nearest the origin.

K. Work-Saving Procedures

1. The workload entailed in applying the procedures described can be reduced in several ways:— Where a considerable number of broadly similar jobs have to be filled, these can be aggregated into one or more groups, each covered by a single row in the matrix. Similarly, groups of men of similar qualifications can form a single column entry each. (If the number of vacant posts in the row doesn't match the number of men in the column, the smaller number describes the number of potential assignments defined by the intersection, and the difference remains attached to the row or column, only the one covering the smaller group being deleted). In the same way, groups of men of *complementary* skill, forming a balanced integrated team, may form the subject of a single manpower column or task row, each. The matrix procedure may however be used, on a smaller scale, to form these individual teams.

2. Since priority is to be given to assignments near the top left-hand corner of the matrix, it might be permissible to assign e values to the jobs in the topmost band in Fig. 4, *from left to right*, terminating each row as soon as it has accumulated, say, four or five favourable e-values. Similarly e-values can be assigned, to the men in the left-hand strip, from the top downwards, only to the point where it becomes apparent that four or five very acceptable assignments are available. Thus the full length of the row or column would have to be explored only for posts which prove difficult to fill or men who prove difficult to place—and there most prior potential pairings would—by definition—be easily identified as mismatches.

3. Finally, jobs and personnel entailing little in the way of specialised skills may be excluded from the formal process altogether, insofar as it may be known that adequate manpower of this type will be available, or that any men not required for the " orderbook " covered by this procedure can be effectively redeployed on other tasks.

L. Continuous Up-Dating

1. All the discussion to date makes the tacit assumption of a " clean " start. However, it is rare for any resource allocation to start without a previous history, and decisions in being. In any case, even if it does so, a major objective of the procedures here put forward is to provide a convenient basis for continued up-dating and revision, in the light of a changing situation. If existing deployments are to remain inviolate, no problem arises. New tasks are fed into the matrix in the proper vertical position, and in due course appear in the " band ", together with new personnel requirements for existing tasks. In the same way, new staff are fed in, in the correct horizontal position, as are staff becoming free from existing commitments. However, we would almost certainly also review existing resource allocations, at least with respect to manning-up important new commitments which could otherwise not be met, or in the attempt to find profitable employment for new (or newly disengaged) highly-skilled staff who would otherwise be inefficiently occupied.

2. In general one would wish to apply a bias against the needless redeployment of staff from existing commitments, but not an absolute barrier. (Indeed an " old " project may be employing the only man who can handle a new task, or may provide the only position in which a new man can be satisfactorily employed). Moreover, this bias may have to vary with the length of service and experience on the job, the criticality of the job, the time before expected

completion, career-planning considerations for the man, etc. The bias cannot legitimately affect the relative R scale of the jobs or the relative W scale of the men, which are defined so as to be sensibly independent of any actual or potential assignments. It can however quite properly modify the desirability or effectiveness of a given job/man pairing.

3. The value of continuity in a post could not in itself make an unsuitable man suitable, and so it seems sensible to represent the value of continuity by a *weighting factor w*, applied to the pairing effectiveness e. This produces a weighted pairing effectiveness E, so that

$$E = w.e.$$

Allowing for the possibility of a positive desire to move a man from a job on which he is already employed and for which he is otherwise well suited, we should permit w to become less than unity. Hence a 5-point scale is suggested for w, increasing in increments of 0·5 from 0·5 to 2·5.

4. It should be particularly noted that the procedures adumbrated in this article have been so designed that all the primary parameters ascribed to jobs, men or pairings—or the secondary parameters derived from them—retain their validity as new jobs, new assignments, new personnel—or the completion of old tasks—change the picture. Furthermore, if there is any change in (or reassessment of) any of the primary factors contributing to:—

job " rigidity ",
personnel " worth ",
job specification,
or personnel profile,

its effect on the " optimum " overall deployment pattern can be derived as a simple clerical or computer operation: all other assessments of primary or derived parameter values can continue to be used to full effect in the process of re-optimisation in accordance with the new data.* Indeed, this is one of the major advantages of such a formalised resource-deployment process.

5. If a new situation arises primarily from one or more new commitments, they can be treated as the horizontal " band " in the matrix. If a new intake of men have to be placed, they become the vertical strip. In order to cope with batch-recruiting, or numbers of men released from completed jobs, a category of posts will have to be included in which men *can* be employed profitably, even though there may not be vacancies which *need* be filled. If new men and jobs become available concurrently, one would normally prefer to pair these, thus avoiding needless dislocation elsewhere. Using them concurrently as the " band " and " strip ", together with appropriate w weighting, would ensure this.

6. If there is a quick " rush job " or a temporary crisis to be handled, we may *prefer* to divert experienced men from a long-term project. In this case, "w" weights of less than unity might be used selectively. Alternatively, this work may be appropriate to some of the able, versatile staff who were deliberately engaged on non-binding commitments. Here, again, low "w" values might be used selectively. Alternatively, however, the W scale of personnel flexibility or " worth " might be ignored, so that assignments in this band are made solely on the basis of job effectiveness. Indeed, the W scale could be *reversed* (choosing the *right-hand* one of two otherwise equal assignments), to ensure that the best and most versatile men are put on to the rush job. These men should then also be easily redeployable in a profitable manner, when the crisis is over. Thus the algorithm proposed provides considerable flexibility to handle the multiplicity of " non-standard " situations which are continually met in resource deployment.

M. The Role of Experience and Judgement

1. Essentially, the processes discussed in this article are an aid to managerial judgement, not a substitute for it. They are valuable only insofar as they may save effort (in initial assessment or up-dating), permit more of the work to be done by a lower grade of effort (including computers), or produce better deployments. However, controlled experiments are rarely possible, and so the quality of the resulting deployments can be assessed only by a subjective judgement. Since we are thus dealing with a non-rigorous procedure, it is all the more important that we derive the fullest possible contribution from human judgement, not only in formulating the input to the system, but in improving its output.

2. This contribution can take a number of forms, as discussed below:—

(a) Overriding the process by subjectively making—or vetoing specific man/job pairings.

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* Subject to overriding at editing by human judgment as discussed in paragraph A2 and in Section M.

(b) Assessing why the process fails to make the desired judgement—or to avoid an undesirable one—and amending the appropriate primary input-value assignments, so that this post—or man—is more correctly treated in future processes.

(c) In order to avoid consistent patterns of amendments to a specific parameter, modifying the weighting factors—or indeed the formulae—thus ensuring that the primary parameters are combined in a more effective manner to generate the desired ones of "rigidity", "worth" and "effectiveness" (or any others that may prove preferable).

(d) Changing the weighting factors or formulae, as in (c), in response to an external overall change in the relative significance of a given consideration or parameter.

(e) Where history has shown certain changes to the initial assignments to be necessary, or hindsight suggests they would have been desirable, invoking an adaptive learning process to change the rules, as in (c) and (d), so that better deployments *would have been* produced in the past, and hence can be expected to result in the present and future.

The greater the scale of the problem (and size of the matrix), the less scope is there for personal knowledge and insight, except for a few critical rows and columns. Hence, progressively, more must our attention then be focused on improving the *rules* of the process, rather than overriding or modifying the individual assignments arising from the application of these rules.

N. The Status of the Proposed Scheme

1. It must be emphasised that:
the primary parameters proposed,
the rules for combining them,
the procedures suggested for man/job pairing,
and even the overall "strategic" objectives,
are all purely pragmatic and empirical suggestions. Their nature and complexity must be decided by each user in accordance with the nature and scale of his resource-allocation problem, the form and extent of the personnel records, job specifications and data-processing facilities at his disposal, his experience—and his preference. However, the basic approach of formalising and rationalising the procedures, and basing them upon mutually independent primary parameters is thought to have merits worth retaining in any such variants or alternative schemes.

2. At the lower extreme of the spectrum of practical applications, the required assignments may be made or reassessed "by eye", using a simple matrix of jobs and personnel, each in an arbitrary sequence. Indeed, given an adequate knowledge of the jobs and familiarity with the personnel, very effective job assignments may be made on the basis of a manager's subjective personal insight, without recourse to any matrix or other, more formalised, procedure. However, it is believed that the efficacy of even this process can but be enhanced by the attempt to rationalise the objectives and criteria involved: even intuitive generalship can benefit from some study of strategy and tactics !

P. General Resource-Deployment Problems

1. The problem of effective deployment of a given body of skilled manpower to a number of projects or tasks, or, conversely, selecting the tasks to be undertaken within given constraints of skilled manpower available, covers also most of the considerations involved in allocating specialised machine tools to a set of jobs or orders, and entails some extra aspects of its own. The allocation of unskilled or identically skilled personnel, identical machine tools, or of financial resources offers yet a further degree of simplification. These examples suffice to show that the subject of this article has applications, *mutatis mutandis* to a wide variety of managerial tasks.

Postscript

This article is intended to stimulate private thought and to provoke public discussion. It does *not* describe methods in use in any organisation known to the author.

HYDROPHONE SIGNALS DUE TO TIDAL AND WAVE EFFECTS

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John Revie joined the RNSS as an Asst. Sc. in 1948, becoming AEO in 1950 and EO in 1959. His service started at the Admiralty Research Laboratory Extension Coulport, with a transfer to the ARL itself in 1950. He was at this stage involved in underwater television and took part in the Affray and Comet searches. After National Service in the RN 1953-1955, he returned to ARL and worked on underwater acoustics. He moved to the ARL Extension, Perranporth as Officer-in-Charge in 1962.

David Edward Weston was educated at Surbiton County Grammar School; and the Imperial College of Science and Technology, joining the RNSS in 1951. All his service has been at the ARL excepting the year 1964-1965 spent as an Exchange Scientist at the Hudson Laboratories of Columbia University. His principal interest has been in oceanographic acoustics; including sound propagation generally, underwater explosions as acoustic sources, signal processing, and recently the various low-frequency acoustic phenomena associated with fish having swim bladders.

Abstract

A hydrophone laid on the sea bed is shown to respond directly to pressure and temperature changes for periods up to that of the semi-diurnal tide, and also shows a strong $4\frac{1}{2}$ Hz vibration signal due to the local water flow. Large voltages are produced by pressure, temperature and streaming effects of the tide; temperature and velocity effects of internal waves; and pressure and velocity effects (the latter sensitive to direction) of surface waves.

The very-low-frequency signals from a hydrophone bottom-laid in shallow water are described here for three reasons. First they are of interest in their own right, and show how varied is the information obtainable from a simple hydrophone. Secondly the account serves as a warning to users of hydrophones of the large voltages (up to 20) which may interfere with the desired acoustic signal. Thirdly the effects have proved very useful in providing a makeshift monitor of various oceanographic parameters, and although there could be development into instruments responding unambiguously to a single parameter it is not wished to stress this possibility. Note that at slightly higher frequencies some further unusual signals have been detected with the same hydrophone[1].

The pressure sensitivity of the hydrophone is 1 volt - 79·3 dB/newton/m^2. The temperature sensitivity through the pyroelectric effect has the high value of 1 volt + 21·6 dB/°C, with a high-frequency limit set by the thermal inertia time constant of about 15 min. For both pressure and temperature the low-frequency limit corresponds to a time constant of about 2 hours, *i.e.* only 3 dB down for the 12½ hour tidal period. The time constant is very high despite the lack of a head amplifier and the connection into 26 km of underwater cable, it comes from the total system capacitance of 2·55μF with leakage resistance about 3 $\times$ 10$^9\Omega$, which in turn is possible due to the use of lead zirconate-titanate (PZT-5H) as piezoelectric material together with modern polythene cable having moulded joints(2). Fig. 1 is an example of the direct hydrophone response.

In addition there is a strong signal of quite a different type, sharply peaked at 4½ Hz. It is due to a flow-excited vibration of the hydrophone and tripod, and is illustrated in Fig. 2. The vibration signal only appears for velocities above about 0·25 m/s (0·5 knot), and then serves as a monitor of the water flow or particle velocity(3). The observed orders of magnitudes of the effects briefly described below may all be shown to be correct.

In winter the pressure changes due to the tidal variations in water height produce swings of about 5 volt. In high summer this effect is swamped by that due to the regular tidal changes in the temperature, with 20 volt swings. Fig. 1 shows a case when the two effects are comparable. In Fig. 2 the shape is largely controlled by the tidal streaming, and since the response does not depend on flow direction there are maxima every six hours odd.

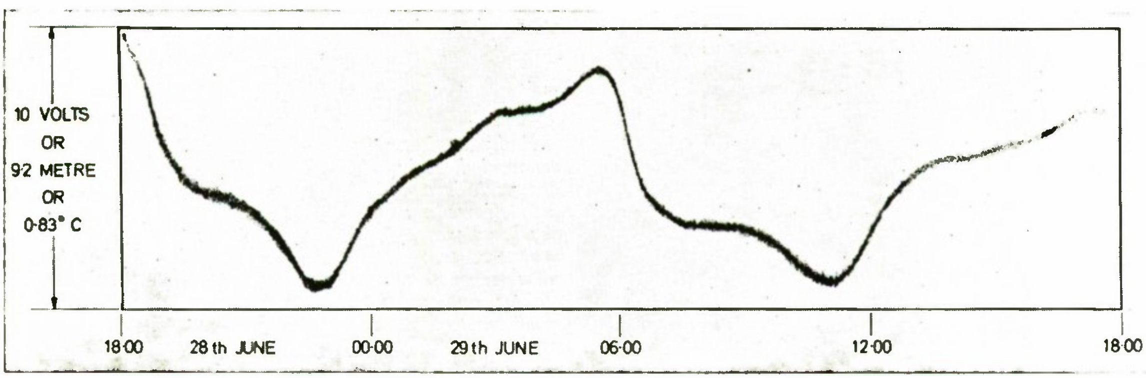

FIG. 1. Example of direct hydrophone signal showing repeating pressure and temperature effects through the tides (1968).

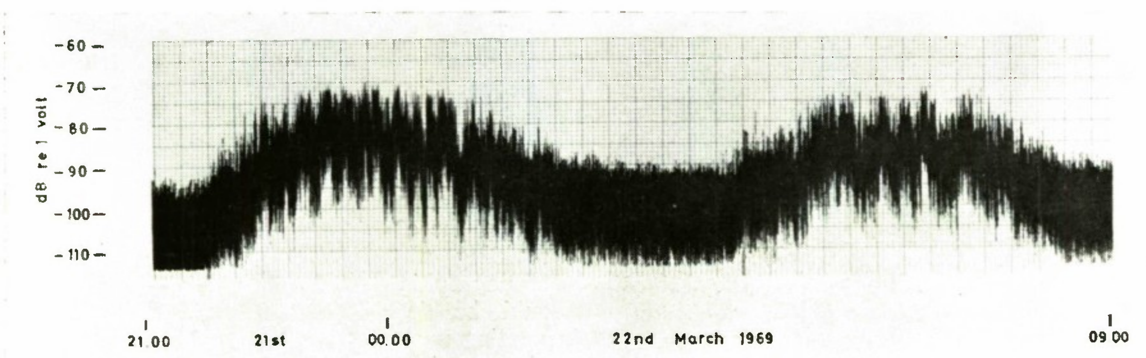

FIG. 2. Example of 4½ Hz hydrophone signal envelope showing water velocity through the tide.

The direct signals for the decade centred on 12½ min. are relatively low, but have been selected by filtering (not illustrated). Statistical analysis over a few months and comparison with other work[4] shows that there are contributions from internal wave effects, the commonest occurring one hour before high water (maximum flow to NE). Typical signal swing for an internal wave is 0·1 volt, and this must be a temperature rather than a pressure effect. In Fig. 2 the internal wave effects may be seen more clearly, with 20 min. oscillations lasting for a couple of hours at the time of maximum flow. These reflect the horizontal particle velocities of the wave motion.

The thickening of the trace in both Figs. 1 and 2 is due mainly to the surface gravity waves, and with a different display these may be resolved and measured. The surface-wave pressure changes at the bottom, somewhat attenuated due to the 40 m. depth, produce a typical swing of 0·1 volt. The surface-wave particle velocities are only strong enough to excite the 4½ Hz vibration when helped by the tidal stream, except in storm conditions. The tidal streaming acts as a biassing or polarizing agent to avoid frequency doubling. From the phase relation between the pressure and velocity effects and the known direction of the tidal stream it is possible to deduce the approximate surface wave direction, normally this is to the NE.

It is possible to follow all these effects through the lunar cycle, and the succession of Springs and Neaps. As a further curiosity note that the lunar month, the tide (12½ hour), internal waves (say 12½ min.), surface waves (say 12½ sec.) and the flow vibration period (0·22 sec.) form a surprisingly accurate geometric progression of periods with ratios of 60.

Acknowledgements

We wish to acknowledge the collaboration of many colleagues including W. R. Stamp, A. S. Merriweather, N. H. Field, C. M. Hubbard, P. H. G. Crane, and Morfydd Edwards.

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H.M.S. *Vulcan*. A.R.T.E. RE-NAMED

The Admiralty Board has granted a new title to the Admiralty Reactor Test Establishment, Dounreay. It is to be known as H.M.S. *Vulcan* with a new functional title of Royal Naval Nuclear Propulsion Test and Training Establishment (R.N.P.T.E.).

The grant of a ship's name is in recognition of the establishment's increasingly significant role in the Royal Navy's nuclear submarine programme.

The new functional title also reflects the part the establishment plays in the training of future submarine crews.

The first recorded British warship named *Vulcan* was a fireship built at Rotherhithe and added to the Navy in 1691. She fought at Barfleur (1692) and Velez Malaga (1704) and was sunk as a breakwater at Sheerness in 1709.

PHOTORESIST AS A HOLOGRAPHIC RECORDING MEDIUM

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John Gordon Castledine is an Experimental Officer at SERL and was educated at Letchworth Grammar School continuing with part-time study at Northern Polytechnic. At SERL he has worked on the development of microwave tubes, neutron generators and holographic projection systems.

Abstract

A technique is described for recording holograms and forming diffraction gratings in Shipley AZ1350 photoresist using the 4579 Å output from an argon laser. A pre-exposure technique is described which not only reduces exposure times but increases the signal-to-noise ratio of the image. It is also shown that the effects of the variable characteristic of the resist can be alleviated by monitoring diffraction efficiency during development.

Introduction

Photoresist has been shown to be a suitable material for the recording of holograms[1,2] and the formation of diffraction gratings[2,3]. However, little information has hitherto been available concerning experimental technique which has to be carefully controlled for optimum results. In addition to describing such a technique, a method is presented for reducing exposure times and decreasing the effects of scattered light on image quality.

Resist holograms are made by exposing the resist, coated on a suitable substrate, to the holographic fringe pattern and immersing in developer. The solubility of the resist in developer is dependent on exposure. Thus a fringe pattern consisting of variations in intensity is recorded as variations in resist height. These variations modulate the phase of an incident wave so as to result in the formation of a reconstructed image.

Positive photoresist such as Shipley AZ1350 has the following advantages over photographic emulsion as a holographic recording medium:—

(1) As the ultimate resolution capability of photoresist is probably determined by molecular dimensions, the material is capable of recording any fringe pattern formed by interference between beams of optical wavelength.

(2) Unlike photographic emulsion, where the dimensions of the developed grain are at least as large as the wavelength of light, photoresist produces little scattering.

(3) We have not observed any significant change in dimension after exposure and processing. All gelatine based materials such as photographic emulsion or bichromates are liable to dimensional changes in the presence of water which is usually a constituent of developing agents.

(4) The spinning techniques employed in the microcircuit industry for depositing resist onto silicon wafers enable optical flats to be easily coated. Holograms on optically flat substrates are essential when real images having maximum resolution are required[4].

Shipley AZ1350 has its peak sensitivity in the ultra-violet and consequently the use of an argon laser as the light source in the holographic recording system results in long exposure times. It has been shown[5] that the 4579 Å output, although of reduced power compared with that obtainable at 4880 Å, is more effective. Therefore, throughout this work, the 4579 Å output from an argon laser has been used.

From the shape of the characteristic of the resist, which we have determined, it is evident that the long exposure times caused by the low sensitivity can be reduced by pre-exposing to a powerful ultra-violet lamp. The pre-exposed resist is then exposed to the fringe pattern. By appropriate choice of pre-exposure the fringe pattern can be formed by object and reference beams of equal intensity so as to result in a large effective reference to object beam ratio, which is necessary to ensure linear recording. It has also been found that this procedure increases the signal-to-noise ratio in the reconstruction.

For maximum efficiency and quality, accurate exposure and development are essential. Variations in the characteristic of the resist necessitate monitoring development as it proceeds. Consequently a simple method has been devised which enables gratings of consistently high quality to be made.

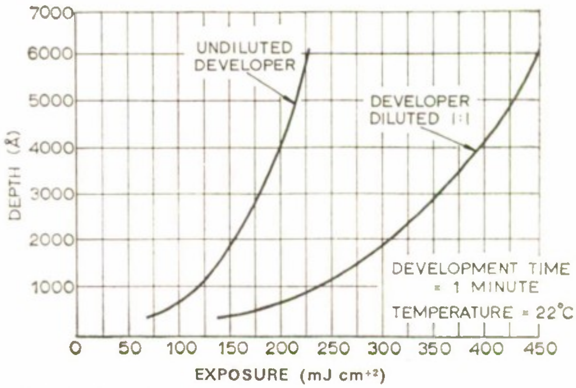

Fig. 1. Depth plotted against exposure for undiluted and diluted developer for a development time of 1 minute at 22°C using the 4579 Å argon laser output to expose Shipley AZ1350 photoresist.

Characteristic A characteristic curve for Shipley AZ1350 has been obtained by plotting depth of resist removed against exposure for a fixed development time and two developer concentrations.

Extreme care in the preparation of substrates is necessary, particularly if these are of silica. Crazing of the resist occurs during development if precautions are not taken to drive off all traces of water from the substrate surface. Consequently, after cleaning with neutral detergent and rinsing in deionised water, the substrate is given a vapour bath in isopropyl alcohol followed by vacuum bake at 140°C.

After spinning the resist onto the substrate a bake at 75°C for 15 minutes is given to ensure complete removal of solvent from the resist. Any traces of solvent in the resist cause variations in the sensitivity of the resist.

The characteristic curve was obtained by exposing separate areas of the resist surface to different exposures, the latter being determined by an integrating meter to reduce the effects of variations in laser output during exposure.

The resist was then developed for one minute at 22°C. After rinsing and drying, the depth of resist removed was measured with a microscope fitted with an interference objective.

For the case of developer diluted 1 : 1 the right hand curve of Fig. 1 was drawn by averaging a number of different curves obtained experimentally. On using neat developer, curves were obtained which were in good agreement with that obtained by redrawing the right hand curve with half the exposure values for a given depth. This redrawn characteristic is the left hand curve of Fig. 1.

Although the characteristic curves of Fig. 1 lack precision we have found that they form a reliable basis for estimating correct exposures and beam intensity ratios.

Diffraction Gratings

In order to assess photoresist as a holographic recording medium, diffraction gratings were made by recording the straight line fringes formed by interference between two plane waves; *i.e.*, a hologram of a plane wave was made using a plane reference wave.

Kogelnik[6] has analysed the efficiency of sinusoidal gratings, *i.e.*, the intensity of the light diffracted into the nth order expressed as a fraction of the intensity of the normally incident beam. For thin phase gratings, which are the type obtained in thin layers of photoresist, the efficiency e is given by the relation:—

$$e = \left[J_n(\phi) \right]^2 \quad \ldots . (1)$$

where n is the diffraction order and ϕ is half the maximum possible phase change between rays incident normal to the plane of the fringes.

If the refractive index is given by μ and the peak to trough height of the grating profile is 2D, then for a transmission grating the efficiency is given by:—

$$e = \left\{ J_n \left[\frac{2\pi}{\lambda} (\mu - 1) D \right] \right\}^2 \quad \ldots (2)$$

whereas for a reflection grating:—

$$e = \left\{ J_n \left(\frac{4\pi D}{\lambda} \right) \right\}^2 \quad \ldots .. (3)$$

Fig. 2 shows the efficiency plotted against ϕ and D for transmission and reflection gratings. It can be seen that the efficiency in the first order can be over 33%.

It is apparent from Fig. 2 that by working over a limited region of the first order efficiency curve a reasonably linear response can be obtained. This assumes, however, a linear relationship between depth and exposure. Reference to the characteristic curves of

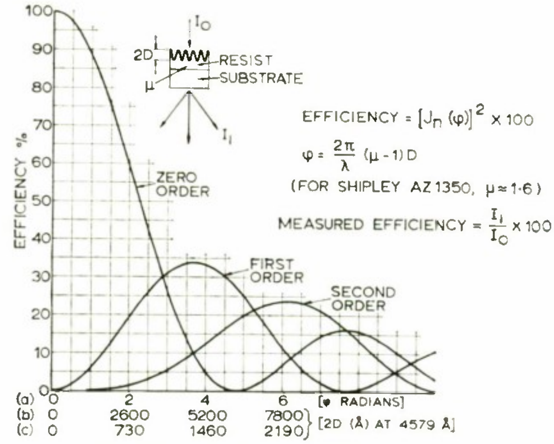

Fig. 2. Efficiency of a phase grating plotted against:—

(a) the relative phase change between rays incident normally at the peaks and troughs of the fringes.
(b) the peak to trough height of the fringes using the grating in transmission.
(c) the peak to trough height of the fringes using the grating in reflection.

Fig. 1 indicates that in order to obtain linearity, while at the same time removing sufficient resist to ensure adequate efficiency, the exposure must be large enough to ensure that a sufficiently steep part of the characteristic curve is used. This in turn implies that the difference between exposures from the dark and light fringes must be small, *i.e.*, that the ratio of reference beam intensity to object beam intensity must be high.

Fig. 3 shows schematically how a sinusoidal variation in height is obtained within the resist

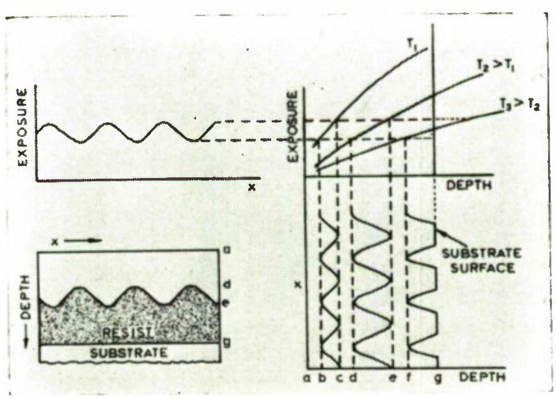

Fig. 3. Schematic diagram indicating the formation of phase gratings in positive photoresist.

as the development proceeds after exposure to a fringe pattern formed by interference between beams of unequal intensities. The peak-to-trough height of the grating profile increases until cut-off at the resist substrate occurs.

Pre-Exposure Exposure times can be significantly reduced by pre or post exposing the resist with uniform illumination. This illumination can be provided by an incoherent source such as an ultra-violet lamp and sufficient pre-exposure can be given in a few seconds. After pre-exposure the resist is exposed to the holographic fringe pattern. The latter can be formed by object and reference beams of equal intensity. This is possible because the exposure due to a dark fringe, which may be zero, is added to the pre-exposure to obtain the total required exposure at a dark fringe. Similarly the total required exposure at a bright fringe is obtained by adding the pre-exposure to the exposure due to a bright fringe. Thus although the fringes may be formed by interference between beams of equal intensity, the overall effect, including pre-exposure, is the same as a recording of the interference pattern from two beams of unequal intensities without any pre-exposure.

The effective reference-to-object beam ratio R can be calculated as follows:—

Let a pre-exposure of A Jcm^{-2} be given. Let this be followed by a second exposure to a fringe pattern obtained by interfering two beams of equal intensity such that the exposure contributed by each beam is B Jcm^{-2}. Therefore the centre of a dark fringe receives a total exposure of A Jcm^{-2} while the centre of a bright fringe receives (A + 4B) Jcm^{-2}. From this it may easily be deduced that

$$R = \frac{A + 2B + (A^2 + 4AB)^{\frac{1}{2}}}{A + 2B - (A^2 + 4AB)^{\frac{1}{2}}} \quad \ldots (4)$$

The actual reduction in fringe exposure time will vary according to the required reference-to-object beam ratio and efficiency. We have found that, by using pre-exposure, typical fringe exposures can be reduced to about a quarter of those necessary when pre-exposure is not used.

In addition to reducing exposure times there is an additional advantage in pre-exposing which makes its use desirable even when exposure times are not an important consideration. In order to obtain a linear recording the reference beam must be effectively more intense than the object beam. There is thus a possibility that stray light caused by scattering of the reference beam off parts of the apparatus will approach the object beam in intensity and hence seriously degrade the image of the object. With a pre-exposure technique the reference and object beams may be made equal and so the effects of stray light are much reduced.

It is notoriously difficult, where coherent light is used, to eliminate dust and other blemishes in the optical system. These defects have a deleterious effect on the reconstructed image. As it is a relatively easy matter to obtain uniform incoherent illumination the pre-exposure technique effectively increases the quality of the reference beam.

Development Although the curves given in Fig. 1 are suitable for approximate determinations of pre-exposure and fringe exposure they lack precision owing to variations in the characteristics of the resist. Consequently it is convenient to adjust the development time for optimum results. Thus some method must be found for observing the efficiency of a diffraction grating as development proceeds.

The apparatus used is shown in Fig. 4. A helium-neon laser beam is incident normally on the grating which is fixed in position in the

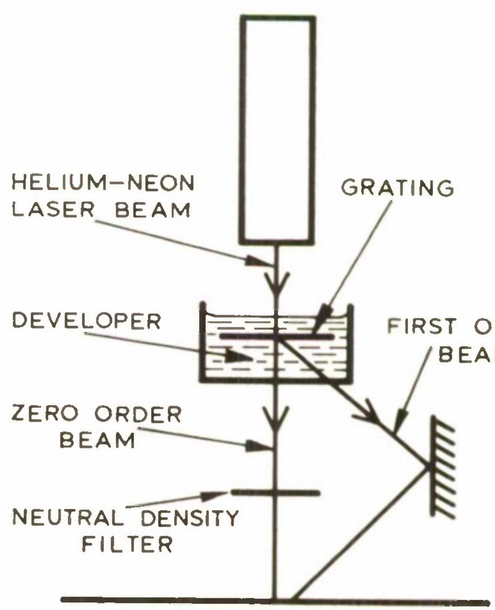

Fig. 4. Apparatus for obtaining optimum development of resist gratings.

developing dish. The intensity of the zero order beam from the grating is compared with that of the first order beam as development proceeds. To compensate for the difference in refractive index between the aqueous developer and the air (in which the grating is presumed to be subsequently used) a neutral density filter is placed in the zero order beam. If a neutral density of slightly more than 2 is used, and development stopped when the zero and first order beams are of equal intensity, a good compromise between efficiency and linearity is obtained. Development is conveniently stopped by diluting the developer with water.

This procedure would appear to be applicable only to diffraction gratings. We have found, however, that satisfactory results can be obtained with non-redundant holograms, *i.e.*, holograms of non-diffusely illuminated transparencies such as micro-circuit masks, by observing the increase in intensity of the first order beam with time. This always increases rapidly to a maximum and gradually decreases. If development is stopped as soon as the initial maximum has been reached, satisfactory holograms are obtained. We have not attempted to make holograms of diffusely illuminated objects. These holograms could be monitored by incorporating a non-diffusely illuminated region in the scene *e.g.*, in the case of a three-dimensional object a mirror might be so placed so as to reflect the object beam onto the hologram.

Conclusion and Results

By employing pre-exposure and by monitoring diffraction efficiency during processing, gratings of up to 30% efficiency and holograms capable of resolving a few microns across a field 20 mm in diameter have been made.

Fig. 5 shows an optical photomicrograph of a grating made by the processes described. Fig. 6 shows a scanning electron micrograph of the same grating. The resist layer was initially 7500 Å thick. The peak to trough height of the grooves is 1300 Å and the height of the peaks above the substrate is 7000 Å. The lateral distance between the peaks is 6800 Å being equivalent to almost 1500 line pairs per millimetre. This grating had an efficiency of nearly 30% in reflection *i.e.*, after aluminising. In transmission the efficiency was much lower, in agreement with Fig. 2.

It is advantageous to work in the reflection mode because the smaller peak-to-trough heights that are required enable exposure times to be reduced and more linearity to be obtained.

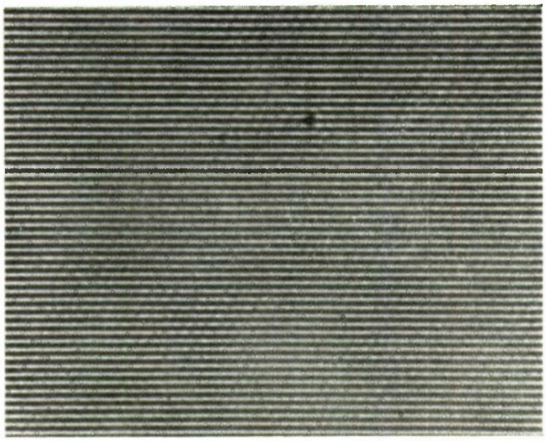

Fig. 5. Optical photomicrograph of part of grating made in photoresist by two-beam interference.

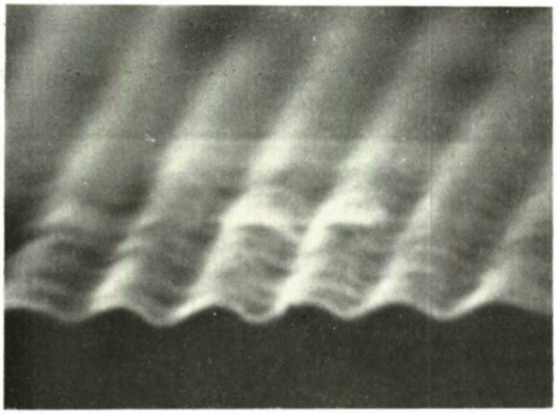

Fig. 6. Scanning electron micrograph of grating.

Acknowledgements

We should like to express our grateful thanks to D. P. Cooper for his help with the photoresist, W. P. Barr for computing Bessel functions and A. Calverley for the scanning electron micrograph.

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WORLD RECORD DIVE

At the Royal Naval Physiological Laboratory

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Dr. Peter Bennett has been engaged on research into hyperbaric and underwater problems since he joined the RNPL in 1953. Graduating B.Sc. as an External Student of the University of London in 1951, he was awarded a University of Southampton Ph.D. (Physiology and Biochemistry) in 1964. He is an internationally acknowledged authority on the physiological problems of deep diving, having contributed over 60 papers and two books on the subject. From 1966 to 1968 he was on approved loan to the Canadian Defence Research Board, Toronto to supervise the installation of the first hyperbaric research chambers and initiate and head a new group to study hyperbaric physiology.

As readers of the March issue of *J.R.N.S.S.* will know, a highly successful world record simulated dive to 1,500 feet for 10 hours was carried out at the Royal Naval Physiological Laboratory from 3 - 18 March 1970 by two volunteer R.N.S.S. members of the Laboratory, Mr. John Bevan and Mr. Peter Sharphouse. The dive included up to 24 hours at 600 ft., 1,000 ft. and 1,300 ft. and 1 hr. at 1,100 ft., 1,200 ft. and 1,400 ft. The scientific programme was co-ordinated by Dr. Peter Bennett. Medical Safety and the decompression profile were the responsibility of Surgeon Commander Peter Barnard, R.N., and Chief Chamber Controller was Mr. Jack Eaton.

The dive formed part of a planned series of dives to probe the limits of human activity underwater and was extensively monitored scientifically. Such care was vital due to evidence from experiments at Marseille in June 1968 by the COMEX organisation (Compagnie Maritime D'Expertises) and Dr. Ralph Brauer of the Wrightsville Marine Biomedical Laboratory, North Carolina of a so-called " Helium barrier "—the High Pressure Nervous Syndrome (H.P.N.S.) apparent at depths greater than 1,000 feet characterised by " motor difficulties, especially trembling fits, imprecise and unco-ordinated movements and balance disturbances, a decrease in mental alertness, tendency to apathy, drowsiness and a slowing of understanding and premature modifications of the brain waves (E.E.G.), slight at first but

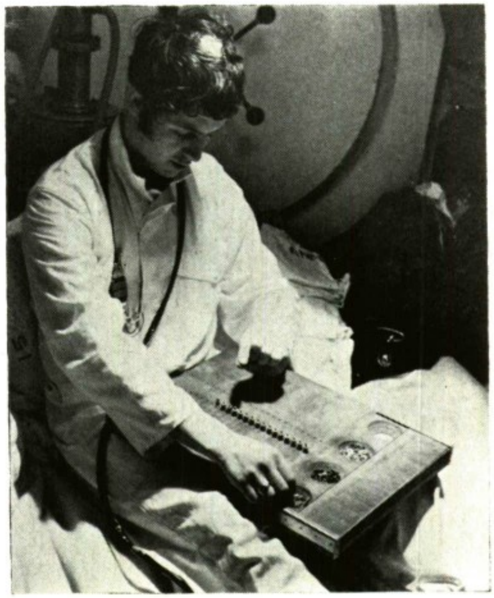
showing increased anomalies until they reached alarming proportions from 35 ats (1,160 ft.)". The E.E.G. changes were particularly important as the subjects themselves felt they could descend further but the occurrence of theta activity (6 c/s) and slow brain waves suggested otherwise and the dive was abandoned after only four minutes at 1,189 ft. It was noted that the H.P.N.S. was 'more pronounced' when the pressure was higher or the rate of pressurisation greater and it was believed that the H.P.N.S. would result in convulsions at about 1,500 ft.

However in February 1969, as described in the May 1970 edition of *J.R.N.S.S.*, a world record 'wet' dive was achieved in the Deep Trials Unit at the R.N.P.L. in which three Swiss divers spent three days at 1,000 ft. and five hours under water at 1,150 ft. Sponsored by the Bataffse International Petroleum Co. and with excellent collaboration between the Swiss and British Staff concerned, the scientific results were such that serious doubt was cast on the existence of this "Helium barrier".

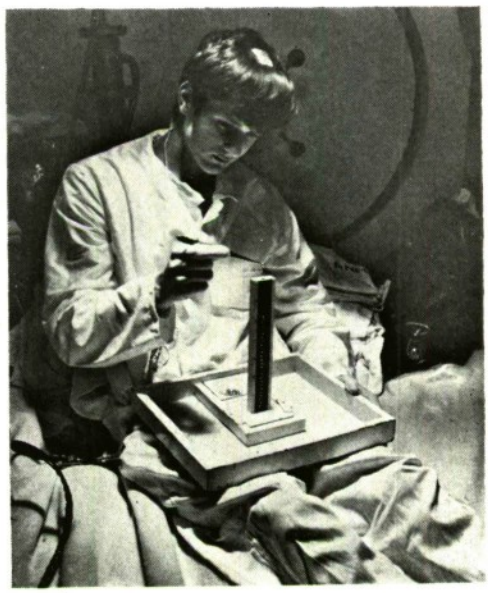
The dive to 1,500 ft. therefore, was planned in stages with a slow rate of compression so that the risk of helium tremors would be reduced and the data could be studied for both short (1 hour) and saturation (24 hour) exposures before proceeding to the next stage. In this way it was hoped to exceed the limits of 1,189 ft., probe the H.P.N.S. and determine its aetiology and importance to diving to both very deep and continental shelf depths (600 - 800 ft.).

The men spent just over 15 days in the 16 ft. by 5 ft. pressure chamber, including 5½ days at depths greater than 1,000 ft. and 3½ days at depths in excess of the 4 min French/American dive. Compression initially was to 600 ft. at 6 min per 100 ft. where 11 hrs. of tests were made during almost 24 hours at this depth. After a further 24 hours at 1,000 ft., with 11 hrs of tests, an hour was spent at 1,100 and 1,200 ft. This was followed by compression to 1,300 ft. with nine hours of tests. On Friday 6th March Bevan and Sharphouse were compressed to 1,400 ft. for an hour before attaining 1,500 ft. for eight hours of tests during a 10 hour stay.

At the time of going to press (April 1970) it was possible to give only a glimpse of the enormous amount of valuable data obtained from these experiments. Excluding control data on the surface, a total of 22 hours of measurements are available pertaining to helium



John Bevan performs the Purdue Peg Board Test during the 1500 ft. dive. The test measures manual dexterity.



Peter Sharphouse carries out the 'Ball Bearing Test' which was one of the tests used to quantify the 'helium tremors'.

John Bevan lies on the bicycle ergometer pedalling (out of picture) while his respiratory functions are recorded.

John Bevan (left) and Peter Sharphouse emerge from the pressure chamber at 4 p.m. on 18th March 1970 after over 15 days inside, of which 3½ days were spent 300 ft. deeper than man has reached ever before.

Peter Sharphouse carries out the 'Tremor Test', with a special tremor transducer attached to his middle finger measuring the degree of helium tremors.

tremors, frequencies of the E.E.G., auditory evoked responses, manual and mental tests of performance, pulse rate, oral temperature, subjective impressions. In addition urine was collected every 24 hours for study of electrolytes, stress hormones and pH. Blood samples were taken and a full medical check carried out before and after the dive. Measurements of respiratory function at rest and during moderate exercise were made by Dr. Morrison. Surgeon Commander Young recorded changes in alveolar gas tensions and blood pressure and Mr. Wilton-Davies the electrocardiogram. A helium voice unscrambler, developed by Dr. Gill at A.R.L., was tested to 1,500 ft. and proved excellent.

Similar data is available also from earlier preliminary dives, on the same subjects, for exposures to 450 ft. and 300 ft. and the detailed correlation of the data available over 24 hours at 300 ft., 450 ft., 600 ft., 1,000 ft., 1,300 ft. and 1,500 ft. will necessarily take time.

Initial conclusions from the results, however, suggest that the helium 'barrier' may be exceeded, but considerable care is required in the choice of profile to reach depths such as 1,500 ft. Compression must be slow and there must be stops of at least 24 hours at interim depths to permit the 20 hours apparently necessary for the changes in the electrical activity of the brain, such as the appearance of theta waves, to return to normal. When deep, only small additional pressure increases should be permitted before allowing adaptation. Careful selection of subjects may reduce the severe tremors and possibly also the E.E.G. changes, the incidence of which varies significantly with the individual.

An important finding is that there is no helium narcosis, the performance changes being due to deterioration in manual dexterity as a result of helium tremors which are most severe immediately during and after compression. Confinement for 16 days produced no psychological problems but calcium, magnesium and phosphorus excretion were decreased.

Ventilation at depth during both rest and exercise was slightly increased, probably due to the increased density of the breathing mixture and possibly to other factors such as the unavoidable temperature changes. The relation of respiratory rates and tidal volumes for a given level of ventilation altered considerably, the rates decreasing with depth and tidal volumes showing a corresponding increase. Alveolar carbon dioxide tensions were normal during rest and exercise at all depths, indicating adequate ventilation. A bradycardia was observed at depth while at rest and exercise but the effect was no worse at 1,500 ft. than at shallower depths.

It is considered that with suitable care and caution man may dive both deeper and longer than 10 hours at 1,500 feet. Certainly at 1,500 feet man can perform moderate work without respiratory embarrassment and considerably greater work appears possible. Finally, the existence of the High Pressure Nervous Syndrome is confirmed but it is a barrier that can be circumvented.

TORPEDO HISTORY

Mr. G. J. Kirby of the Admiralty Underwater Weapons Establishment is compiling a *History of the Torpedo* and would be pleased to hear from readers who can supply anecdotes, information, photographs or drawings (which will be promptly returned after copying) and hardware. The latter, of any size and condition, are required for a newly formed Torpedo museum at RNAD, Priddy's Hard, Gosport.

SPECIFYING THE INTERFACE BETWEEN DESIGN AND TEST ORGANISATIONS

Commander H. W. Young, M.A., R.N.
Admiralty Surface Weapons Establishment

Hugh William Young was educated at Durham School and Emmanuel College, Cambridge, graduating in 1950. Appointments in the Royal Navy have included work on gun fire control systems, a post-graduate course at the Royal Military College of Science, trials on an air-to-air guided weapon, and technical application on ADA systems. He is currently engaged in work on support and maintenance policies for all Naval surface weapons equipment.

Abstract

Automation is being used increasingly by both design and test organisations. To be fully effective automated design systems need to be extended to produce test data. In addition the automated processes themselves lack the flexibility of the intelligent human designer and tester. These considerations necessitate a specification of the interface between design and test organisations which is more detailed and precise than that required for the manual processes. A study of such a specification is being undertaken in the Weapons Department of the Royal Navy.

This paper outlines the current state of the study. It shows the need for the specification and discusses the overriding requirement for it to be equally applicable to both manual and automated design and test procedure. More detailed requirements are considered under the following headings:—

(a) The depth of testing.
(b) The allocation of test points.
(c) The test sequence.
(d) The test data language.
(e) The test instrumentation.

The principles underlying these characteristics are described and are used to derive techniques which could form the basis of the specification. The extent to which they would meet the requirements is then discussed, together with the progress made so far towards their realisation. Some wider implications of these techniques are also considered.

The paper concludes that provided the work in progress so far is successful, an integrated specification which covers the design/test and design/maintenance interfaces for both manual and automated processes should be possible, and that it would need to be at National or International level to have the required authority.

Introduction

In the past both the design and test processes were carried out manually. Because of the flexibility of intelligent men operating the design and test organisations there was no need to give a detailed and precise specification of the test information which had to pass between them. Furthermore test organisations cover a variety of purposes from development proving tests and production tests through maintenance tests after repair, and this made such a specification more difficult.

In recent years, however, both design and test organisations have been influenced by automation. Computer aided design is becoming a well-established technique and automatic test equipment has been shown to be a practical and necessary aid in overcoming the problem of ever increasing test load. Thus automated design is developing on the one hand and automated testing is evolving quite independently on the other. While the details of the advances in each discipline are not necessarily interdependent, it is necessary in order to realise the full potential advantages of either to establish a standard interface between the designer and the tester.

This interface is the subject of a study (which is continuing) in the Weapons Department of the Royal Navy. The study has shown that parts of the problem have already received a great deal of attention from other sources. For example a method of allocating test points is specified in ref. (1) and a language for test data is described in ref. (2). However the present study makes an approach to the problem as a whole, and aims to show that the extension and synthesis of previous work should make it possible to produce a comprehensive specification of the interface between design and test organisations. The current state of the study is reported in this paper.

Requirements

The requirements of a sound specification for the test data which must pass between design and test organisations will be considered in two parts. The first part covers the requirement for it to be fully compatible with both manual and automatic test and design processes. The second part considers the more detailed features of the specification itself. Any solution to the more detailed problems in the second part must also meet the overriding requirement of the first part.

Compatibility with Automatic and Manual Procedures

The advent of automation to both the test and design tasks has created the situation where either task may be carried out manually or automatically. This situation is represented in Fig. 1. Since both manual and automatic processes are likely to be operating in parallel for the foreseeable future, any specification of the interface must be applicable to all four quadrants of Fig. 1.

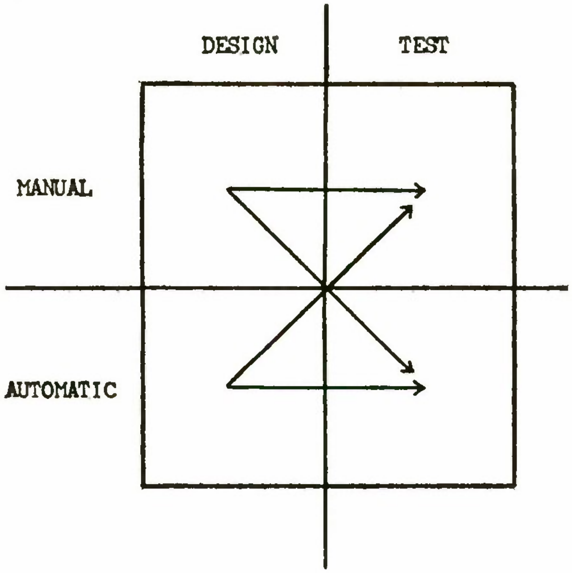


Fig. 1. Manual—Automatic situation.

The extent to which computer aided design can contribute to the generation of test data will depend upon how precisely the design/test interface can be specified. However, computer aided design is inherently capable of assisting in the production of test data because the simulation programmes contain a representation of the signal at each point in the system. In addition, for electronic design, the layout and wiring programmes can generate continuity and insulation check-out data. This topic is discussed in more detail later, but it has been raised here to show that there are many aspects of the automated design process which could be exploited by a precise specification of the design/test interface.

Detailed Characteristics of the Specification

In addition to the overriding requirement that the specification should apply equally to automatic and manual processes, it should also

give precise information on the following aspects of the test data required:

(a) The depth of testing.
(b) The allocation of test points to achieve the required depth of testing.
(c) The test sequence.
(d) The test data language.
(e) The test instrumentation.

The depth of testing is a characteristic which needs to be specified by the test organisation for each unit under test. A numerical index needs to be derived which will specify depth of test precisely so that it can be used to assist in determining the test point allocation. Once test points have been allocated, the test sequence and test data language must be specified. The specification of the test instrumentation can follow.

All these aspects of testing affect both design and test organisations, and require precise definitions if automation is to be fully exploited in each organisation.

In order to study these characteristics in more detail it is necessary to establish some of the principles on which testing is based.

Principles The basic principles in testing will be considered under the following headings:

(a) Depth of testing
(b) Test strategies
(c) Test tactics
(d) Test language structure.

Depth of Testing

The depth of testing can vary from check-out to full diagnostic. The best depth in this continuum depends upon the cost of testing to that depth, the producers and consumers risk associated with the test, the cost of the replacement part at that depth, and the cost of undetected errors.

Test Strategies

There are two basic strategies which will be termed the sequential Strategy and the Non-sequential strategy.

The sequential strategy consists of applying tests and taking readings in sequence, each test reducing the area in which a fault lies until the defective item is located.

The non-sequential strategy consists of applying tests to a large number of items at once and by observing the pattern of results, either to pass all items, or else to identify a faulty item.

Few equipments are simple enough to be tested completely by a non-sequential strategy, though the extension of this strategy is being pursued. In general a sequential strategy is applied to a whole equipment, while non-sequential strategies are restricted to sub-sections. Furthermore, any break in signal from input to output can only be traced by sequential methods. Non-sequential strategies are, however, sometimes forced on the designer by cost considerations in certain areas.

Thus the sequential strategy predominates, and the non-sequential strategy tends to be specialised and localised in its application.

Test Tactics

The requirements for diagnosis are in general more detailed than those for check-out, and usually include them. Since the sequential strategy predominates over the non-sequential, the principles of the test tactics for sequential testing for diagnosis are those which need to be derived. Five such principles can be isolated, and these are described below, and are summarised in the Summary of Principles section.

In order to test an equipment sequentially it must be divided into parts. These parts tend to have a hierarchical structure with major parts containing minor parts and so on. The first principle, therefore, is to establish some form of hierarchical structure. For testing purposes, the elements of this structure should correspond to the functions of the equipment which are needed to carry out its operational task. A second hierarchy also exists corresponding to the physical structure of an equipment. Since physical parts are replaced as a result of diagnosis this hierarchy is important for repair. Ideally both hierarchies should coincide, but several factors including cost, size and weight force the designer to blur the boundaries. This should never be done, however, without considering the consequences on testing, and thus both hierarchies should be isolated and presented to the designer and tester during development.

The functional groupings, or blocks, into which the equipment has been divided are linked by signals. The signal flow lines need to be isolated so that " half split " testing techniques can be applied. This forms the second principle. Some difficulties in applying this principle to complex equipments are discussed later.

Having isolated the signal flow lines, the functions of the blocks along the flow lines need to be identified. This forms the third principle.

The breakdown of an equipment into a series of block diagrams with a hierarchical structure is the basis of the tactics for testing an equipment. However, the way the blocks depend on other blocks needs to be highlighted. The block diagram contains this information but not in an explicit form. A clear indication of dependency forms the fourth principle.

Finally the signals between blocks need to be specified, with tolerances, in as much detail as possible as they form the test data. This is the fifth principle.

These five principles cover the tactics for the sequential testing of equipment. They are based on a sequential strategy, but they do not prevent the use of non-sequential methods in the areas where the latter are better.

It is of interest to note that these same five principles are involved in conveying an understanding of an equipment, as well as in the tactics of testing it, and are thus involved in presenting handbook information. This point is raised again later.

Test Language Structure

Automatic test equipments are like computers in that they are multi-state devices, and like computers they therefore need instructions which form a language structure as follows:

Machine code
: Actual instructions passed to the machine. Specific to one machine

Symbolic language
: Simple, frequently used, groups of machine orders with mnemonic titles. Specific to one machine, or at best a small group of machines.

High level language
: Large groups of machine orders, user orientated, with English-like titles. Machine independent.

Machine codes rapidly give place to symbolic languages, but high level languages with their compilers follow much more slowly. The major disadvantages of machine codes and symbolic languages lies in their machine dependence. It is inconceivable that one specific test machine should dominate the development and in-service life of an equipment and re-writing test specifications is expensive. The flexibility in application conferred by a high level language is an essential feature of a language for transferring test data between designer and tester.

Summary of Principles

Depth of testing can range from check-out to full diagnostic.

There are two test strategies, sequential and non-sequential, with the sequential strategy predominating.

Five principles have been derived which can form the basis of the tactics for testing an equipment. These are as follows:—

(a) Divide the equipment into parts in a way which will show both functional and physical hierarchy.
(b) Isolate the signal flow lines.
(c) Indicate the functional blocks.
(d) Indicate the dependency of functional blocks along the signal flow lines.
(e) Specify the signal between functional blocks.

Test languages have a structure of machine code, symbolic language, and high level language similar to the structure of computer languages. The flexibility conferred by a high level language is essential to the windespread use of automatic test equipment.

Generality of Principles

The principles derived above were formed with electronic equipment specifically in mind. They can be seen to have more general application however. Any device which performs some function has signal flow lines, generally arranged in a hierarchy. Such devices include mechanical equipments, computer software and human organisations. The signal may be a flow of electrons, a shaft movement, or an exchange of information. In all these cases the logic which causes the device to fulfil its function can be represented by signal flow lines and functional blocks, which have dependencies and signal specifications. To test any of these devices the principles derived so far will be relevant.

There is nothing new in these principles, and they have been applied frequently in the past. However, their formal statement is an aid to deriving techniques which can be used in a specification of the design/test interface.

Techniques

The application of the principles derived in the previous sections involves the development of three techniques which seek to apply

these principles systematically. They require some practice to acquire and details are given in other documents, but a broad description follows in order to make the specification of the design/test interface more concrete. Some of the difficulties in applying the techniques to complex equipments and systems will also be discussed.

Technique for Specifying Depth of Testing

The main requirement for this technique is that it should produce a numerical index which will describe depth of test precisely. The current approach being investigated is to use the fraction of the replaceable elements of the unit under test in which a fault may lie after test. Thus an index value of 1 represents a check-out test, and an index of 0·5 represents a depth of test which will diagnose a fault to at worst half the replaceable elements in the unit under test. This work has just started, and ideas are not yet firm, but the goal is to derive a process which will give systematic guidance in selecting a depth of test index. Full time effort is being devoted to this problem at the present time.

Technique for Implementing the Tactics of Testing

The main feature of this technique is the use of block diagrams to implement the first three principles of the Test Tactics section. These diagrams are arranged to show signal flow lines clearly from left to right, with feedback from right to left. Both funtional and physical hierarchical structures can be shown by coding the outlines of the blocks in various ways, or alternatively by the use of colour, using differing shades of blue for the functional hierarchy, and shades of grey for the physical hierarchy. Block diagrams in similar configurations are also used for text, as well as for circuit symbols. As an example which shows the generality of this technique the signal flow of the argument of this paper is shown in Fig. 2.

The last two principles, which involve showing dependencies and specifying signals are applied to form dependency charts and signal specification tables. This technique can be applied as the Development Documentation System (D.D.S.) during design. Its applications are described in more detail in Ref. (3) and it is fully specified in Ref. (4).

Problems, and an Approach to their Solution

There are certain problems in applying the technique to complex equipment which need to be clarified. The chief of these lies in isolating the signal flow lines, which may tend to become segmented by switches or gates, and hence become difficult to follow. However, by analysing the control mechanism which organises the switching of the main signal flow lines in these cases, a dominating set of signal flow lines can generally be isolated. This can be formalised by the concept of a different dimension for the control signal flow lines.

An extension of this concept can link the software signal flow line to the hardware signal flow lines in computer systems. A more detailed discussion of this somewhat abstract idea which gives coherence to the signal flow lines of complex systems, is given in Appendix A.

Suitability of D.D.S. for Human and Automatic Use

To return to the main discussion, a technique has been evolved which will implement the principles on which the tactics of testing are based. It was devised for human use, and its effectiveness in this role has been demonstrated. It remains to show that it is applicable to the automatic environment.

The use of automatic test equipment requires that the unit under test should have its test points and test sequences allocated during design, and the dependency chart is well suited to this purpose, provided a sequential test strategy is used. It can be made to take account of the cost, reliability and accessibility of replaceable elements in arriving at a test sequence. The technique is, therefore, compatible with automatic testing.

Computer Graphics can make the manipulation of the diagrams required by the technique very easy. A computer programme for deriving a dependency chart from a block diagram has already been run using teleprinter input and output, and programmes designed to exploit existing graphics software facilities to implement these and other rules of the technique are planned.

Computer Aided Design will eventually use graphics input and output, and the test tactics technique, when extended to computer graphics, is capable of fulfilling this function, forming a faster man/machine interface than the teleprinter. In this role it could enable the designer to assess the testability of a design very rapidly.

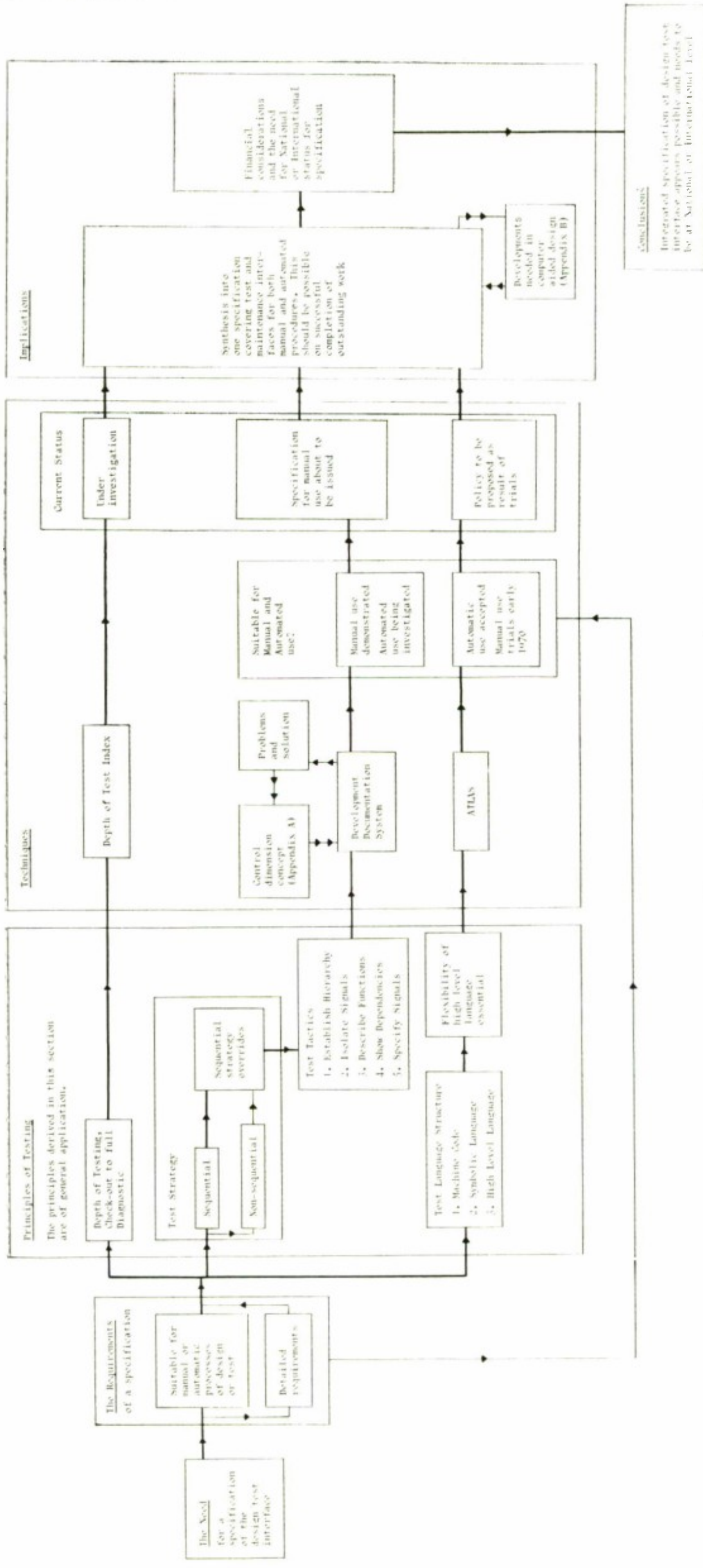


Fig. 2. Block diagram of the Argument for the Specification of the Design/Test Interface.

Thus, in general, the technique appears to be applicable to both the manual processes of the present and such computer aided processes as can be foreseen.

Present Status of Applications in the Royal Navy

The technique described above can be applied in two ways. It can be used as a design aid and communication system during development, and it can also be refined and developed as a maintenance aid for use in service.

Specifications in the Naval Weapons Specification series are being written for both applications, but it is the former application as an aid to designing testable equipment which is the principal concern of this paper. In this application it is provisionally called the Development Documentation System (DDS) and is covered by Ref. (4).

The first draft of Ref. (4) for manual applications was issued in July 1968. Two hundred and fifty copies have been produced, so that information on DDS has been given a wide distribution, and the system is winning general acceptance in Naval circles. The final version is now nearing completion, and it is planned to submit it to the Director General Weapons (Naval) for approval early in 1970.

The applications of DDS to computer aided design and to automatic testing have not yet been demonstrated, but investigations so far have not revealed insurmountable difficulties.

Technique of a High Level Test Language

There is at present only one high level test language being seriously considered. This is the Abbreviated Test Language for Avionics Systems (ATLAS) described in Ref. (2). This "pure" language may well evolve dialects in the same way that Algol 60 in the computer field has given rise to dialects corresponding to each type of machine. From a human point of view, all dialects are understandable to someone trained in the pure language, but for machine use the correct dialect is essential though translation between dialects should be comparatively simple.

Suitability of ATLAS for Human and Automatic Use

ATLAS was designed for automatic use, and although human aspects were kept in mind, the author knows of no reports of trials designed specifically to test how easy it is to write and read ATLAS, or what training load is involved. A design organisation cannot reasonably undertake to produce test data in ATLAS only, nor can a test organisation accept it, until suitability for use by humans together with the training load involved, have been assessed. The alternative, which is to have both English and ATLAS test data, is wasteful, and violates the principal requirement that the design/test interface specification should be equally applicable to automatic and manual design and test processes, outlined in the section Compatibility with Automatic and Manual Procedures.

Preliminary trials have been carried out at H.M.S. *Collingwood* and these are described in Appendices B and C. They show that unskilled men can read ATLAS after only 2½ hours instruction, although the times taken for the tests are longer than the times taken when the instructions are written in English. More trials are needed to see how far this time can be reduced by further training and practice, but there is also a more subtle problem which is discussed in the following paragraphs.

One of the features which the trial emphasised was the distinction between a test specification and a test procedure. The former is a statement of the parameters to be measured, which, ideally, should be independent of the test equipment to be used. The latter is a statement of the series of instructions for a man to carry out those measurements with a particular piece of test equipment. By virtue of its machine independence ATLAS is a language for writing test specifications, not test procedures. Thus, in concept, there is a need for a "compiler" for humans as well as for automatic test equipment. On consideration four distinct locations for this ATLAS/human compiler can be envisaged as follows:

(a) The human brain by training.
(b) The use of the "comment" facility of the ATLAS language.
(c) The test equipment handbook.
(d) The Unit Under Test handbook.

A more detailed study of this problem is needed to decide how the ATLAS/human compiler should be placed amongst these four locations. Greatly improved performance in testing could be expected from such a study and its implementation.

The current instructions for test specifications in Defence Guide 5008 call for a pure statement of the test parameters. However, it is clear from investigating existing test specifi-

cations that this requirement is not often met and the test specifications, in fact, frequently depend on the test instruments being used. If tests are to be carried out by man or machine and if test data is to be generated by Computer Aided Design in the future, then true test specifications which are machine independent will be required, but they will need compilers for both machine and human use. So far ATLAS appears to be a reasonable high level language for test specifications and appears to be inherently capable of being read by both man and machine in this sense. The compilation problem for both men and machines, however, has not yet been solved.

Present Status of Application in the Royal Navy

Initial results of the investigations into the human aspects of ATLAS will influence the extent to which it is applied as a universal test language in the Royal Navy for human and automatic use. When they have been analysed, a proposed high level test language policy will be submitted to the Director General Weapons and the Chief of Fleet Support for consideration.

Summary of Techniques and the extent to which they meet the requirements

The requirement to specify the depth of testing can be met by a numerical depth of test index. The basis for such an index is under full time investigation.

The requirement for allocating the test points and test sequence depend on the strategy and tactics employed. The tactics of sequential testing can be implemented using the technique of the Development Documentation System, involving block diagrams, dependency charts and signal specification tables. A final specification for the manual use of DDS will be ready for agreement shortly. The automatic aspects of DDS have not been demonstrated, but investigations have been encouraging and have revealed no insuperable difficulties.

ATLAS is currently the only technique for meeting the test data language requirement. It was designed specifically for automatic use and its human aspects are being investigated in a series of trials the first of which was completed in March 1970. On the results of these trials a high level test language policy will be formulated. The specification of the test instrumentation emerges from the use of the ATLAS language.

Implications

The requirements of a specification for the design/test interface have been discussed, together with techniques which show promise of meeting them, and the current progress in the Royal Navy in investigating and implementing those techniques. Some of the implications which this work has for future developments will now be briefly considered.

Technique	*Manual Use*	*Automated Use*
Depth of Test Index	Full time investigation	No Detailed Work
Development documentation system	Specification about to be circulated for agreement	Overall approach has been investigated Planning of detailed work is about to start Investigations so far reveal no insuperable problems
Atlas	Initial trials of suitability for human use. Completed March 1970 Compiler problems remain	Compiler problems remain, and are being investigated by industry

Fig. 3. Techniques, and the Current State of their Investigation in the Royal Navy.

Synthesis

If the work described above produces satisfactory results, the three techniques involved will fulfil the main requirements of the design/test interface. At that stage, therefore, they will be ripe for synthesis into one single specification. Such a specification would go a long way toward meeting the design recommendations in Ref. (5).

Furthermore the Development Documentation System forms the basis for producing the in-service handbook as well as the test documentation, so that a single specification would cover the interfaces between design and maintenance as well as test organisations. Both these interfaces have tended to be neglected in manual design processes, and they will be similarly ignored in the computer aided design process unless positive action is taken to include them. The type of developments which need to be encouraged are briefly described in Appendix D. The precise specifications of the design/test interface is one way of initiating these developments.

Financial Considerations

The developments such as those described in Appendix D require investment of considerable sums of money and effort by design organisations. Similarly the use of automatic test equipment involves considerable investment by the test organisation. This investment will not take place unless there is a sufficient market for the specified product. Naval Weapons Specifications alone do not command such a market, and the author considers that only a specification at a National or International level would have the required authority.

Conclusions

The basic requirements for the specification of the interface between design and test organisation have been stated. The overriding requirement is that the specification should apply to both manual and automated test and design procedures.

Techniques which show promise of meeting these requirements have been outlined, and the state of present investigations have been described. They are summarised in Fig. 3.

If the outcome of these investigations is satisfactory, an integrated specification which covers the design/test and design/maintenance interfaces for both automatic and manual processes would be possible.

In order to command investment to the extent required, such a specification would have to be at National or International level.

APPENDIX A

Control Dimensions

The chief problem in analysing complex equipments for test purposes centres round the isolation of the signal flow lines. For a number of reasons, the signal flow lines may be chopped up by switches into short segments. This can happen in quite simple equipments, but the classic example is the digital computer which is a multi-switch device. The standard technique described in the main paper can deal with the situation when the switches are under direct human control. However, difficulties begin to appear when switches are not under human control, but are operated by the equipment itself, sometimes in complex sequences. There is a tendency in these circumstances to deny the validity of the flow line concept. The flow lines are still there, however, because the equipment performs some task. They are to be found in the control function which determines the switch positions.

The control function, discussed above, can be thought of as lying in a different dimension from that containing the basic segmented and switched signal. To visualise this concept, the main circuit can be thought of as lying in the horizontal plane while the control circuit lies in a vertical plane, interpenetrating the horizontal plane at the switches. The dominating signal flow lines will now appear in the control plane, and this must be analysed first before the segmented signal flow in the main circuit can be understood.

The concept of control dimensions can be carried still further in the case of digital computers. Here the main circuit in the horizontal plane is the " Slice ", linking registers, highways and arithmetic unit with very short, very segmented, flow lines. The switches and gates in the slice plane do not operate at random, or the computer would not carry out any function. They are controlled in a logical way by the control circuitry, which can be represented as a vertical control plane.

But a computer by itself will not carry out any functions. It requires a programme, which now contains the dominant signal flow lines for

this particular function. These flow lines form a third dimension. Thus this concept links the flow line ideas of hardware with those of software.

The complexity does not end here, and the software flow lines themselves can become segmented by software switches or jump orders, adding further dimensions. Still further segmentation of the software signal flow lines can occur under the control of the supervisor programme and priority logic applied to demands for machine time. Thus four or five dimensions could be quite common. Once the signal flow lines have been analysed and isolated, the remaining principles and techniques can be applied in their appropriate dimensions.

The control dimensions concept is based on the principle that if any device, no matter how complex, is to carry out some task, the flow lines will be present, and that they are intrinsically capable of analysis. Upon this analysis depends both the understanding and testing of the device, and hence ultimately its maintainability.

APPENDIX B

Human Readability of ATLAS

Introduction The ATLAS test language appears to offer the possibility of using the same test specification for both manual and automatic testing, giving an attractive saving in the effort required to prepare and maintain test specifications. However, leaving aside the separate question of whether it is economically feasible to construct an ATE capable of interpreting full ATLAS, it is not obvious that a semi-skilled grade of technician will be able to take an ATLAS test statement and translate it into the actions required to test an electronic unit manually. This report describes the results of a trial conducted to assess the human readability of ATLAS; some tentative conclusions are given.

Outline of the Trial

Some difficulty was found in selecting a suitable piece of hardware on which to base the trial. This arose through two basic requirements:—

(a) the equipment must have well defined Test Points

(b) the English test specification must be a complete statement of the test requirement.

A high proportion of equipments in service were found to have either badly defined Test Points, or a test specification written in terms of a special test set. However, a suitable equipment was eventually found, and two test sequences extracted from the handbook. The first related to a sub unit, and consisted of simple DC voltage checks and AC signal output checks. The second test sequence related to a Printed Circuit Board, and was more complex in requiring measurement of distortion and operator intervention to adjust a Pre-set control. Test Sequence No. 2 is listed in Appendix C, in both the English and ATLAS versions.

This provided four test tasks for the purpose of the trial. These will be referred to as:—

E1 — English version of Test Sequence 1

A1 — ATLAS version of Test Sequence 1

E2 — English version of Test Sequence 2

A2 — ATLAS version of Test Sequence 2

The original intention was that, for each sequence, half of the men would do the ATLAS version first, while the other half did the English version. This would have enabled a direct comparison between the performance using the ATLAS test statement alone and the performance using the English test statement. Unfortunately, lack of time prevented the completion of the trial programme; the results actually achieved are given in Table I.

Conduct of the Trial

Sixteen Leading Radio Electrical Mechanics, who had just completed their qualifying course, took part in the trial; they had no previous experience of computer languages and were unfamiliar with the equipment used for the test task.

TABLE I

Test Task Order

	1	2	3	4
1	E1–27	A1–35		
2	E1–23	A2– *		
3	A2– *	A1–37	E1– *	
4	A2–75	E1–24	A1–24	
5	E1–25	A1–25	A2–73	E2–24
6	A1–50	E1–20		
7	A1–50	E1–20	E2–38	A2–26
8	A1–40	E1– 7	A2– *	

(* = Test terminated by supervisor due to shortage of time).

The trial began with $2\frac{1}{2}$ hours "Read only" instruction in ATLAS, including a worked example of an ATLAS test sequence. The men were then split into eight groups of two, and the order in which they carried out the test tasks, together with the time (in minutes) taken for each test sequence, is shown in Table I.

As well as speed, the mistakes made by each group were recorded. The majority of the mistakes seemed to be caused by inadequate knowledge of the test equipment used. The two areas in which errors were made in interpreting the ATLAS test statements were:—

(a) attempting to execute the DEFINE statements in the preamble before arriving at the appropriate APPLY statement

(b) confusing 'HI' and 'LO' when connecting a negative power supply.

These problems would appear to be associated with a lack of familiarity with ATLAS, rather than with a basic inability to comprehend the meaning of the ATLAS statements. Otherwise, the accuracy of translation of the ATLAS statements into human actions was remarkably good, although some groups gave the impression that the process of translation was not thought out but was intuitive.

For comparison purposes, the significant data from Table I can be summarised as follows. The average times taken (for first attempts at a particular task) were:—

A1 (not having done E1)	45 minutes
E1 (not having done A1)	25 minutes
A2 (not having done E2)	74 minutes
E2 (not having done A2)	38 minutes (sample of 1 only)

The reactions of those taking part in the trial were generally quite favourable to the use of ATLAS as a means of writing down test instructions; some groups specifically commented on the fact that ATLAS test statements were unambiguous. There was a general feeling that more 'COMMENT' within the preamble would have been of assistance to the human tester. However, this raises problems connected with test equipment training, and the use of the comment facility was deliberately kept to a minimum in order not to confuse the trial with side effects.

Conclusions The trial was of short duration and explored only a limited area of the full ATLAS capability. Nevertheless, it would seem reasonable to conclude that ATLAS test specifications can be used for manual testing by technicians, instead of the English test instructions to which they are accustomed, with no loss of accuracy. Lack of familiarity with ATLAS was clearly a part cause of the reduced speed of execution of the ATLAS test tasks observed in the trial; a prolonged trial would be needed to assess whether ATLAS was ultimately less efficient for the human tester than English.

APPENDIX C
Specimen Test Tasks

Test Sequence 2—English Version

1. Connect a −24V supply to Terminal 3.
2. Connect a +24V supply to Terminal 7.
3. Connect the RF Signal Generator CT352A to Terminals 5 and 7 (earth) and adjust its output to 100 kHz.
4. Connect a 1·8 kohm resistor (5%, $\frac{1}{4}$ W) across Terminals 6 and 7.
5. Connect Oscilloscope CT436 across these same terminals to monitor the output waveform.
6. Adjust potentiometer fully clockwise (maximum gain).
7. Adjust the input signal level (CT452A) until distortion is just showing on the output waveform.
8. Verify that the output level is not less than 3V p-p.
9. Adjust the input level to 300 mV r.m.s. and check that the output level is not less than 1·92V p-p. Record the voltage.
10. Turn the potentiometer fully counter-clockwise and verify that the reduction in output level is at least 4 : 1.
11. Adjust potentiometer to maximum.
12. Disconnect the RF Signal Generator from Terminals 5 and 7 and reconnect it to Terminals 4 and 7.
13. Adjust the input level to 300 mV r.m.s. at 100 kHz and observe that the output level is within 12% of the previous level (Step 9) and not less than 1·92V p-p (680 mV r.m.s.).
14. Adjust potentiometer to obtain an output of 650 mV r.m.s.
15. Connect the Multimeter 8 SX (set to 250 μA d.c.) between Terminals 8 and 7 (negative). A meter reading of 110 - 170 μA should be obtained.
16. With the output level set to 650 mV r.m.s., disconnect the 1·8 kohm resistor and note the new output level across Terminals 6 and 7. It should be 1·16 - 1·46V r.m.s.
17. Disconnect all test equipment.

TEST SEQUENCE 2—ATLAS Version

```
 200000  BEGIN, ATLAS PROGRAM £
     01  DEFINE, ' DCP—λ ', SOURCE, DC SIGNAL, VOLTAGE, −24·0V ERRLMT
         ±0·5P, IMP MAX 1·0 OHM, CURRENT MAX 0·1A,
         CNX HI PIN−3 LO PIN−7 £
     02  DEFINE, 'RFS−1', SOURCE, AC SIGNAL, VOLTAGE ( ) RANGE 0·1V
         TO 1·0V, RATE MAX 0·1V/SEC INCREASING, FREQ 100·0 KHZ
         ERRLMT ± 1·0 PC, IMP 75·0 OHM ERRLMT ± 25·0 OHM,
         CNX HI ( ) LO ( ) £
     03  DEFINE, ' LOAD ', LOAD IMPEDANCE, RES 1·8 KOHM ERRLMT
         ± 5·0 PC, PWR−LMT 0·25W, CNX HI PIN−6 LO PIN−7 £
     04  DEFINE, ' D−METER', SENSOR, (DISTORTION), AC SIGNAL,
         VOLTAGE MAX 3·0V, FREQ 100·0 KHZ ERRLMT ± 1·0 PC,
         CNX HI PIN−6 LO PIN−7 £
     05  DEFINE, 'RFMETER−3V', SENSOR, (VOLTAGE) AC SIGNAL, VOLTAGE
         MAX 3·0V, BANDWIDTH 100·0 KHZ, IMP MIN 1·0 MOHM,
         CNX HI PIN−6 LO PIN−7 £
     06  DEFINE, 'I−METER', SENSOR, (CURRENT), DC SIGNAL, CURRENT
         MAX 250·0UA, IMPEDANCE 5·0 KOHM ERRLMT ± 10·0 PC,
         CNX HI PIN−8 LO PIN−7 £

E200100  APPLY, ' LOAD ' £
C        START OF TESTING £
     01  APPLY, 'DCP−1' £
S    02  APPLY, 'RFS−1', 0·1V, PIN−5, PIN−7 £
     03  PRINT, MESSAGE, ADJUST POT (TO ONE END OF TRAVEL) TO GIVE
         MAXIMUM READING ON RF METER £
     04  MONITOR, 'RFMETER−3V' £
     05  ADJUST, 'RFS−1' £
     06  TO REACH, 'D−METER', LL 5·0PC UL 10·0PC £
C        IF A DISTORTION METER IS NOT AVAILABLE THEN USE AN
         OSCILLOSCOPE. THE MINIMUM AMOUNT OF DISTORTION THAT CAN
         BE SEEN BY EYE IS ABOUT 5 PER CENT £
     07  VERIFY, 'RFMETER−3V', GT 1·0V £
     08  GO TO, STEP 200200 IF NOGO £
     09  ALTER, STEP 200102, VOLTAGE 0·3V ERRLMT ± 10·0MV £
     10  VERIFY, 'RFMETER−3V', GT 0·68V £
     11  PRINT, RESULT, 'MEASUREMENT' £
     12  GO TO, STEP 200002 IF NOGO £
     13  SAVE, 'MEASUREMENT', 'OP1' £
     14  PRINT, MESSAGE, ADJUST POT TO OTHER END OF ITS TRAVEL £
     15  WAIT FOR, MANUAL INTERVENTION £
     16  CALCULATE, 'LIMIT' = 'OP1'/4·0 £
     17  VERIFY, 'RFMETER−3V', LT 'LIMIT' £
     18  GO TO, STEP 200204 IF NOGO £
     19  PRINT, MESSAGE, RETURN POT TO OPPOSITE END OF TRAVEL £
     20  WAIT FOR, MANUAL INTERVENTION £
     21  REMOVE, 'RFS−1' £
     22  APPLY, 'RFS', 0·3V, PIN−4, PIN−7 £
     23  CALCULATE, 'UL' = 'OP1' *1·12 £
     24  CALCULATE, 'LL' = 'OP1' *0·88 £
     25  VERIFY, 'RFMETER−3V', UL 'UL' LL 'LL' £
     26  COMPARE, 'MEASUREMENT', GT 0·68V £
     27  PRINT, RESULT, 'MEASUREMENT' £
     28  GO TO, STEP 200206 IF NOGO £
     29  PRINT, MESSAGE, ADJUST POT TO OBTAIN A READING OF 0·65V
         ON RF METER £
     30  MONITOR, 'RFMETER−3V' £
     31  VERIFY, 'I−METER', UL 170·0UA LL 110·UA £
     32  GO TO, STEP 200208 IF NOGO £
     33  REMOVE, 'LOAD' £
     34  VERIFY, 'RFMETER−3V', UL 1·46V LL 1·16V £
     35  GO TO, STEP 200210 IF NOGO £
     36  GO TO, STEP 200252 £

 200200  PRINT, MESSAGE, FAILED MAX GAIN CHECK, STEP 200107 £
     01  GO TO, STEP 200250 £
     02  PRINT, MESSAGE, FAILED GAIN CHECK, STEP 200110 £
```

```
     03  GO TO, STEP 200250 £
     04  PRINT, MESSAGE, FAILED GAIN ADJUSTMENT CHECK, STEP 200117 £
     05  GO TO, STEP 200250 £
     06  PRINT, MESSAGE, FAILED OUTPUT LEVEL CHECK, STEP 200125 £
     07  GO TO, STEP 200250 £
     08  PRINT, MESSAGE, FAILED OUTPUT CURRENT CHECK, STEP 200132 £
     09  GO TO, STEP 200250 £
     10  PRINT, MESSAGE, FAILED OPEN CIRCUIT VOLTAGE CHECK, STEP 200134 £

200250   PRINT, MESSAGE, PROGRAM TERMINATED £
     51  FINISH £
     52  PRINT, MESSAGE, TESTING COMPLETED £
     53  FINISH £
     54  TERMINATE, ATLAS PROGRAM £
```

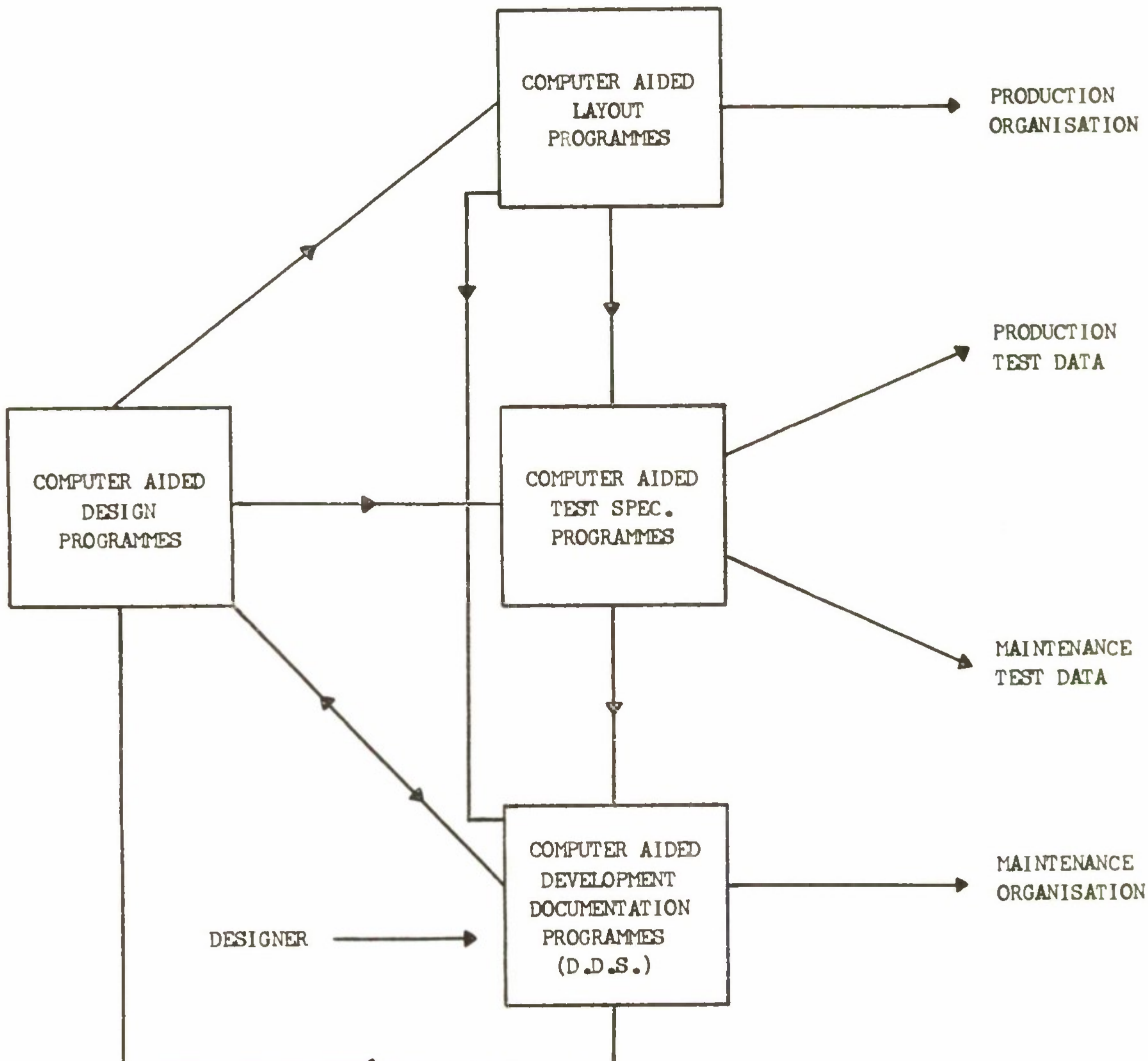


Fig. 4. Integrated Computer Aided Design Process

APPENDIX D

Future Developments in Computer Aided Design required to Assist Test Organisations

Computer aided design for electronics is gradually emerging from an era of unconnected programmes into an era of design systems. The first signs of this are the grouping of analysis and simulation programmes into a design group while component layout, module allocation and back wiring programmes from a computer aided layout group. This is followed by the linking of the design and layout groups. To be fully effective these systems need to develop programmes or groups of programmes to assist in producing documentation and test specifications. An integrated design system of this type is shown in Figure 4.

Taking Fig. 4 in more detail, the circuit could be evolved and checked using the analysis and simulation programmes via the graphics terminal and the Documentation group of programmes as in input/output device. When these ideas have crystallised information would be available to generate the block diagrams and dependency charts by the Documentation programmes. These would be displayed for the human assisted allocation of test points, test parameters and test sequences. The values of test parameters are capable of being generated by the simulation programmes, with tolerances, and could be used as raw material for the Test Specification Programmes.

At the same time the circuit configuration will be used by the Layout Programmes. These programmes are currently used to generate terminal identification code names and insulation and continuity checks, and this information would also be needed as raw material for the future Test Specification Programmes. With these data and human intervention, again via the graphics terminal, the Test Specification could be generated directly in a high level test language.

In the last stages of the process the terminal names, components lists and layout diagrams generated in the Layout Programmes are available to be fed into the Documentation Programmes, and together with the test data could be inserted in the correct place by these programmes—all without human errors.

The ability to tie all these programmes together, and to link them with a data bank, involves a Design System Language, apart from quantities of hardware. A language with the required characteristics is being developed by Racal Limited, and is called Circuit Calculating Language (CCL). Its aim is to knit the various separate programmes used in computer aided design into a system, without having to re-enter each new programme from the outside world, possibly with a different data format in each case.

The need for developments of this sort are emphasised in Ref. (5) and unless they take place many of the advantages of Computer aided design will be lost and test organisations will continue to suffer from equipment designed without testing in mind. These developments depend upon a precise specification of the design/test interface with sufficient authority to cover a large number of customers and producers.

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AN ANALOGY BETWEEN SUNSPOTS, THE PLANETS AND SATELLITES

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Abstract

When the planets and the satellites of each planet are separately arranged in order of their diameters there is a strong tendency for them to pair off. It is argued that the statistical significance is at least 1 in 50,000. As a partial explanation of this it is suggested that the origin of the planets and satellites might have been somewhat analogous to the present formation of the sunspots since these also have a strong tendency to pair off and to produce "descendants". This explanation, if correct, would support a magnetohydrodynamic theory of the origin of the solar system.

The purpose of this note is to point out that the planets and satellites have a strong tendency to pair off in regard to their sizes. Since sunspots have a similar tendency this suggests that the mechanism by which the planets and satellites were formed was analogous to that which now produces sunspots although of course on a much grander scale. This conjecture is somewhat vague, but it is not vacuous for it at least implies a magnetohydrodynamic theory for the origin of the solar system, such as the theories of Birkeland, Berlage, and Alfvén. These theories were considered critically by ter Haar and Cameron[1] in physical terms. Here the analogy between sunspots and planetary systems is formulated in terms of raw observations: to make a *prima facia* case without reference to the physics. The justification of the approach is partly that the magnetohydrodynamic equations are still too difficult to solve, so that the physical arguments are inconclusive.

The conjecture is not implausible since the planets and satellites were created at a time when the "Sun" presumably had over 100 times its present angular momentum. I have written "Sun" in quotes because at that time it might have been in a nebulous condition, and not recognizable as a star. Something analogous to the streamers of the corona (which are known to be associated with sunspots) might have contained enough mass to produce planets.

Any magnetohydrodynamic theory for the origin of the solar system has something in common with the above conjecture, but the present note gives two arguments that are not a necessary part of a magnetohydrodynamic theory.

Note first that sunspots can have "descendants"[2] and usually occur in groups, as if the Sun was still doing its best, with inadequate resources, to give birth to planets with satellites.

Second, note that sunspots usually but not always occur in associated pairs and *the planets and satellites show a similar feature.* This fact is of interest in itself irrespective of the analogy with sunspots. In order to see this pairing we can arrange the planets, and the satellites of each planet, in ascending orders of their diameters or radii, as in Table I.

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TABLE I. Diameters of the planets and satellites.

Sun (Planets)(i)	*Jupiter*	*Saturn*	*Uranus*	*Neptune*	*Mars*	*Earth*
·38	14	100	300	180	6*	2200
·52	15	300			10*	
			600*	3000		
·96*	17	300*	800*	3700(i)		
1·00*	19	400*				
			1000*			
3·38*	35	600*	1100*			
3·72*	35	600*				
9·03*	100	700				
10·97*	150	800				
	1790*	3000				
	2020*					
	2770*					
	3120*					

Notes on Table I.

(i) Pluto is often thought to have once been a satellite of Neptune (it is sometimes closer to the Sun). It has been listed under Neptune with slight licence.

(ii) The diameters of the satellites are not accurately known and different estimates are given in different places. I have taken the figures from the 1967 edition of the *Encyclopedia Britannica* where the sources are given.

(iii) For the planets the figures are means, with $\oplus=1$. The other figures are given in miles.

(iv) The meaning of the asterisks is explained below.

The various subsidiary bodies (planets of the sun and satellites of the planets) nearly all fall quite readily into pairs as shown by the spacings in Table I. The only exceptions are Titan (Saturn), Miranda (Uranus), Nereid (Neptune), and the moon of the Earth. It is tempting, although perhaps far-fetched, to suggest that the Earth once had another moon and that it fell into the Pacific ! This is now as good a theory as the familiar one that the present moon arose from the Pacific. The latter theory is thought to be inconsistent with the age of the moon samples. Then again perhaps the moon was once a planet and was captured by the earth, as proposed by Gerstenkorn: see, for example, Alfvén and Arrhenius[3]. Gerstenkorn's theory neither helps nor hinders the statistical significance of the pairings: if the moon is assumed to have been a planet then we would still be tempted to assume that it once had a mate.

The figures are striking enough so that a statistical test is hardly necessary, especially as ten of the eighteen pairs are spacially adjacent, as well as being adjacent in the ordering by diameters. These ten pairs are marked with an asterisk in the table. Given the pairing by diameters the expected number of spacially adjacent pairs among them is $4/7 + 6/11 + 4/8 + 2/4 + 1/2 + 1 = 3{\cdot}62$. If we ignore the Mars pair, Deimos and Phobos, which had to be adjacent, we have nine " successes " with an expectation of 2·62. Assuming a Poisson distribution, the probability of having nine or more successes is only 1/3000. Of course Deimos and Phobos are strikingly similar, although they are irrelevant to the argument if they are artificial satellites as suggested by Shklovskii[4]. The argument is strengthened if this suggestion is brushed aside as again too far-fetched or already refuted[5].

The logarithms to base 10 of the ratios of the consecutive diameters of the planets, as listed, are ·14 (·26) ·02 (·53) ·04 (·39) ·08, where the figures not in parentheses refer to the planets as paired, and the figures in parentheses refer to the others. These seven logarithms form a sequence which increases and decreases alternately, the chance of which " at random " is 1/64. This suggests that our pairing of the planets is not an artifact, but has some physical explanation. Of course the pairings of the planets in Table I appear good to the eye, but this gives quantitative expression to the judgment. The similar sequence for Jupiter is even more striking, being ·03 (·054) ·049 (·26) ·00 (·46) ·18 (1·17) ·06 (·13) ·05, again increasing and decreasing alternately. This time the " random chance " is 1/1024. The chances of 1/3000, 1/64, and 1/1024 are all independent. The statistical significance is overwhelming in spite of the few exceptions to the pairing off. To have a few exceptions is not surprising on the basis

of our conjecture since sunspots are not always associated in pairs.

It might be objected that we have here used some special selection since we obtained the tail-area probabilities of 1/64 and 1/1024 only from the satellites of the Sun and Jupiter. In order to allow for special selection we should "pay" a factor of at most $\binom{7}{2}=21$. This must surely be an overpayment since the satellites of Mars clearly make a good pair, but we can afford to be extravagant. We may combine the tail-area probabilities 1/3000, 1/64, and 1/1024 by Fisher's method[6]. This gives an equivalent tail-area probability of 1/1,000,000 and so, after paying the above-mentioned penalty, it is still reasonable to put the over-all significance at about 1/50,000. This seems to establish a clear tendency of the planets and satellites to occur in pairs. The analogy with sunspots is of course offered in a more tentative spirit.

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NEW TRIALS VESSEL

A new ship designed to provide mobile preparation firing and control facilities for weapons and research vehicles, was launched on Tuesday, May 5, 1970 at the Cartsburn (Greenock) Shipyard of Messrs. Scott's Shipbuilding Co. Ltd.

The ship, which was named *Whitehead* after the torpedo development pioneer will also be fitted with equipment for tracking weapons and targets, and for analysing the results of trials.

The vessel was named by Mrs. I. McIntosh, wife of Rear-Admiral I. S. McIntosh, D.S.O., M.B.E., D.S.C., the Director General Weapons (Naval), and the religious service was conducted by the Rev. W. Cameron Wallace, Industrial Chaplain attached to the Scott Lithgow Group.

The *Whitehead* has a deep displacement of 3,040 tons, an overall length of 320 feet and a beam of 48 feet. She will be propelled by two English Electric diesel engines. The ship will carry a complement of 10 officers, 32 ratings and accommodation for 15 trials and scientific staff.

Historical Note

Robert Whitehead, the 19th century engineer, originally developed a torpedo which could carry 18 lb. dynamite at six knots for 400 yards underwater. In 1870 two Whitehead torpedoes were tried by the Royal Navy at Sheerness. Within weeks the Government had bought the rights of manufacture for £15,000.

A RING PROCESSING PACKAGE FOR USE WITH FORTRAN OR A SIMILAR HIGH LEVEL LANGUAGE

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Whilst primarily a computer programmer she spent nearly two years as Chief Operator of the KDF9 computer, retiring early in 1968.

Mrs. Lawson joined the RNSS in 1957 in the Mathematics Group at ARL. She is now mainly employed writing software in machine code for the KDF9 and PDP8 computers.

Dr. Yuille was trained as a naval architect at Vickers - Armstrongs (Shipbuilders) Ltd., and studied for his degrees at Glasgow University. He joined the RNSS in 1952 and carried out research on ship structures at NCRE for eight years. He then spent six years at the Ship Department, Bath, as adviser on structural matters. Early in 1967 he joined the Mathematics Group at ARL in order to develop a system for computer aided design of ships.

Abstract

Many applications of a computer, particularly in engineering design, utilize relationships between blocks of data and require a facility for building and manipulating data structures which permit the expression of these associative relationships. This report describes a software package that enables associative data structures to be represented in a computer store by means of rings of address pointers connecting blocks of data in an orderly manner. The package has been implemented on a KDF9 computer with a disc store operated by the Egdon 3 system. The software is written in machine code but by means of a set of small auxiliary routines operations may be carried out by calling FORTRAN subroutines. By this means manipulations of associative data occupying up to two million words may be included in FORTRAN programs. By writing different auxiliary routines the package could be used in ALGOL or another high level language. Implementation on another computer would not be difficult.

Introduction

Many modern applications of a computer, particularly in the fields of computer aided engineering design and computer controlled drawing or display, are concerned with collections of objects, each of which has properties represented by some data, arranged in such a way that the association of one object with another is explicit. For example, certain objects may possess some common property or they may possess some hierarchical structure such as a family tree. Data representing such a collection of objects is known as an associative data structure. It is required to represent an associative data structure in a computer store in such a way that it may undergo re-arrangement and modification when required and so that the associative relationships may be determined easily when the data structure is entered at any point.

An association between two blocks of data in a computer store may be represented by adding to one block of data a word which contains a pointer to the address of a similar word added to the other block of data. By building on this concept multiple associations may be achieved by adding several words to each data block and by using many address pointers to link the blocks together in some orderly fashion. The simplest arrangement that will satisfy the requirements of the previous paragraph is one in which the pointers form rings that may be traversed from one block of data to another, eventually returning to the first, and to designate one position in each ring to be its starting point. It is convenient, however, to have pointers that enable a ring to be traversed in either direction and also to make it possible to go directly to the start of a ring.

The various published implementations of this concept differ in their arrangement and handling of the pointers, in their methods of execution, and in the command languages by which the systems are used. A review of several schemes was published by Gray (1967). All required compiler type programs to translate commands, written in the chosen terminology, into machine code or, in the case of APL (Dodd, 1966) for example, into PL/1 statements and sub-routine calls. There is as yet no standard terminology for describing associative data structures, or operations on them, and some of the published command languages are far from easy to use.

The object of the present work was to provide a ring processing software package that permitted the representation of large complex associative data structures which could be operated upon in a manner which was easy to program. There is a tendency, at present, for engineering applications programs to be written in FORTRAN (in the hope that they will run on different computers without having to be re-written) and it seemed to be desirable to provide a set of operations within the framework of a proven high level language rather than a separate facility. For these reasons our ring processing routines, written in a low level language, are accessible to a programmer by calls to FORTRAN subroutines. (The package uses small auxiliary routines to connect it to the FORTRAN and it would be easy to enable it to be used with another high level language, for example as a set of ALGOL procedures). This obviates the need for a special compiler to include ring processing operations and permits the programmer to use the jump facilities of FORTRAN to embed the basic ring processing operations in sophisticated program loops if he so desires. The subroutines permit all required operations on the structural data but the detailed organisation of the rings is carried out automatically. The names given to the subroutines are concerned with ring processing operations and the interpretation in terms of the data structure represented depends entirely on the application.

The ring processor has been implemented on a KDF9 computer and is designed to fit into the Egdon 3 operating system (Poole 1968). The system makes use of a four million word disc store and it was desired to use this to store large data structures which could be operated upon by running various programs in the computer. It was decided to hold each element of a ring in one 48 bit word. Although the use of forward, backward and ring start pointers in each element would have been desirable this would have restricted each address pointer to 14 bits and confined the total size of the structured data to less than 16384 words. It was therefore decided to use 21 bit pointers which allow the data to occupy up to two million words if required. (Each element of a ring contains a forward pointer and either a backward or a ring start pointer as will be described in more detail later). The data is held on pages in files on the disc store and pages are brought into the core store when required. By this

means the ring processing package effectively permits the extension of the addressable memory within a FORTRAN program to about two million words.

Data Structure in Computer Store

The basic item of the representation of an associative data structure comprises a number of contiguous computer words and will be called an entity. Many different types of entity may exist in the same ring structure. A typical entity is shown in Fig. 1. The first word is the entity header and into this is packed information concerning its type, region, number and size. The next few words are elements of rings formed by address pointers as described in the next paragraph. (There is a maximum of seven of these only six of which are available for general use). The remaining words of the entity contain data specific to the object represented by that entity; these data may be alphanumerical, *e.g.* the name of the object, and/or purely numerical data concerning one or more properties of the object, depending upon the application.

ENTITY HEADER
ASSOCIATIVE ELEMENT IN TYPE RING
ASSOCIATIVE ELEMENT 1
ASSOCIATIVE ELEMENT 2
RING START ELEMENT 1
RING START ELEMENT 2
DATA WORD 1
DATA WORD 2
DATA WORD 3

FIG. 1. Typical Entity.

The arrangement of a ring is based on that of the CORAL language which was developed at the M.I.T. Lincoln Laboratory (Sutherland 1966). This allows rapid tracing through the ring in a forward direction and permits tracing backwards or to the start of a ring with little extra effort. In our implementation each element of a ring is formed in one 48-bit word of KDF9 store and consists of four parts. Three bits identify the type of element, three bits form a number specifying its position in the entity and the remainder of the word contains two parts of 21 bits each. One of these parts holds the page and relative address of the next element in the ring. One element is the start of the ring and is called a ring start element; all other elements are subordinate to it and are called associative elements. In the ring start element the second 21 bits record the number of elements in the ring. In the associative elements the second 21 bits hold a page and relative address which points either to the ring start element or is used as a backward pointer. A backward pointer always points to an element with a back pointer and rings are formed with start pointers and back pointers alternating as shown in Fig. 2. The less useful pointers are thus stored in half the space but this involves only a small sacrifice of operation time.

The association between two entities is achieved by choosing the associative element, at a given position in one of the entities, and putting it into the ring starting at a given position in the other entity. A third entity may be associated with these two by putting one of its associative elements into the same ring and further entities may be added in the same way.

When it is desired to put one associative element of an entity into the rings starting in two or more other entities a problem arises because an associative element has only sufficient room for the pointers of one ring. This problem is handled automatically by the program by letting it join rings together by means of a device called a knot. (These were called nubs in CORAL). A knot is a two-word block of store each word of which is an element of a ring. When an associative element of an entity is to be put into two rings it becomes the start element of an auxiliary ring of two associative elements, one in each of two knots. The other two elements of the two knots become associative elements in the two rings of which the entity is to become a member. If it is desired to place the element of the entity in a further ring the number of knots is increased by one, and so on. Thus the effect of the auxiliary ring is to provide an extension of one associative element of an entity when (and only when) required. It is best thought of in this way so that the original associative element in the entity may be regarded as one associative element tied to more than one ring. A ring without knots will be referred to as

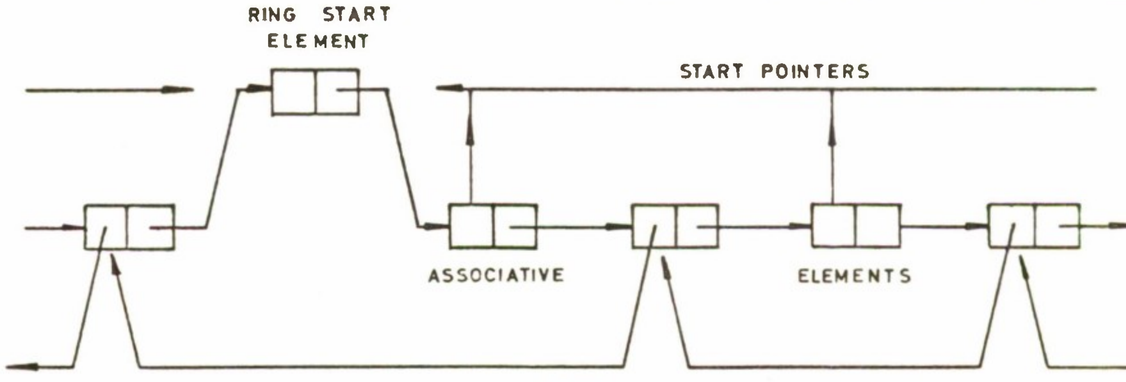

FIG. 2. Arrangement of Ring.

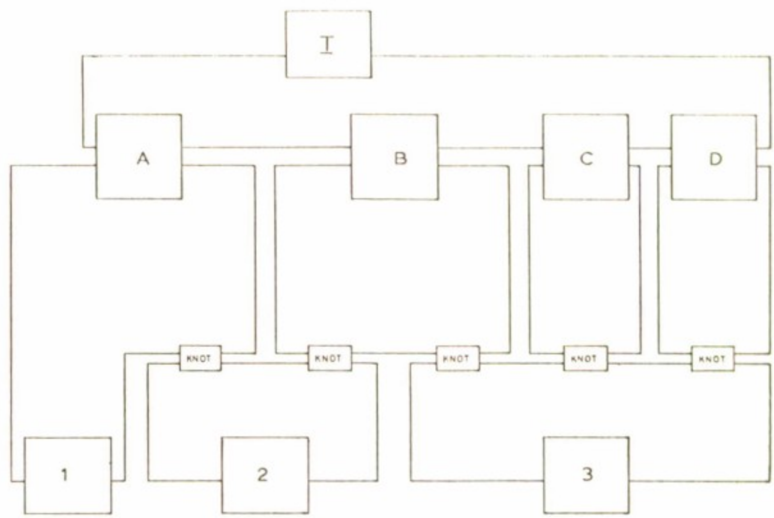

FIG. 3. Typical Ring Structure.

a simple ring and one with knots will be called a complex ring. The creation, organisation and deletion of knots is handled entirely by the processing package and need not concern the applications programmer.

A small associative data structure is shown in Fig. 3 and illustrates the use of knots to join rings. Entities **A, B, C** and **D,** are in a simple ring having its starting element in entity **I.** Entity 1 is in one ring starting in entity **A.** Entity 2 is in two rings starting in entities **A** and **B.** Entity 3 is in three rings starting in entities **B, C** and **D.** The associations represented in Fig. 3 are completely general and depend upon the meaning given to the data structure in a particular application. For example, in part of an information system entity **I** might represent a particular subject, entities **A, B, C** and **D** papers on that subject (with titles and sources held as data) and entities 1, 2 and 3 the authors of the papers (with their names held as data).

The limitation on the number of ring elements in an entity may appear to imply a limitation on the number of rings that can have their ring starts in a given entity but this is not so in practice. For most applications this limitation will not be a restriction. If it is, however, the difficulty may be overcome by defining an entity with up to five ring start elements and by putting one or more of these entities into a ring starting in the original entity thus effectively extending indefinitely the number of ring starts there. If the latter is to have a large number of associations (as is implied) it may be convenient to include in the extra entities some words of data for identification or they may be identified solely by their positions round the ring starting in the original entity.

Organisation of Storage

The system is primarily intended to run on a computer with disc as well as core store. (There is, however, a version of the software that uses only the core store). For the KDF9 computer a software paging supervisor enables the whole of the available store to be addressed in one way. A suitable amount of core store is set aside for manipulations of the data structure and into this pages may be read from the disc. The core store set aside must be able to accommodate at least six pages but the system will run more efficiently if more pages can be accommodated. Each 21 bit address pointer, to a ring element or an entity, specifies a page number and the address relative to the beginning of the page. When a pointer is encountered the paging supervisor examines its list of pages in core. If the required page is present the page and relative address are converted into the appropriate core address. If the page is not present it is read into a free part of the array allocated to pages in core store. Then the page in core which has remained unused for the longest time is read baek to the dise (except in certain circumstances to be mentioned later) lcaving a free space in the array for the next page required from the disc. While the unwanted page is being written onto the disc the pages in core may be used with little interruption to the program.

After many manipulations of a data structure it may be anticipated that linked entities may be scattered over many pages. To inerease efficiency, entities may be made in any of 63 regions and the pages for one region only hold entities in that region. Calls for entities in one region will bring into core pages holding other entities in that region. Thus, by setting up the representation of a data structure so that the most frequently used associations occur within particular regions the programmer can decrease the probability that further pages will have to be read from the disc before operations on the ring structure may continue. Also, in some manipulations of a data structure it is convenient to set up an auxiliary structure which is later discarded. If this is set up in a separate region its deletion, when no longer required, does not involve the ereation of gaps in the main ring structure which may have to be removed by the data compacting routine.

On the KDF9 disc store the pages of each region are held in a separate file in the Egdon 3 system. In addition to the obvious advantage, that the user has all the facilities of the Egdon archiving system, this helps the operation of the Egdon system during which, as a safeguard against disc failure, a periodic dumping to magnetic tape is carried out of all files that have been altered since the last dumping. With a ring structure held in several files only those regions that have been changed need to be dumped.

Facilities Available

The software comprises a User Code package plus some small auxiliary routines that enable operations on the ring structure to be carried out by calling FORTRAN subroutines in the normal way. Thus programmers are able to include operations on associative data in programs written in a high level language. There are facilities for:

(a) Creating and deleting entities.
(b) Establishing and altering the associative links between entities.
(c) Tracing round rings of entities.
(d) Interrogating entities.
(e) Obtaining access to data held in the data parts of entities.
(f) Compacting the data structure so that it oceupies the smallest possible space.

The subroutines that provide most of these facilities are summarised below. Full details are given in the Users' Manual which consists of the substance of this report, together with information about the use of the package in the Egdon system, bound in loose leaf form so that it may be kept up to date. The subroutines require the programmer to specify a number of integer variables, or their values, in the usual way. The definitions of these are given below together with the names allocated to them in this description.

JA = Position of associative element in entity.
JD = Position of data word in entity.
JS = Position of ring start element in entity.
KEA = Entity page and relative address. There must be at least three variables KEA1, KEA2, KEA3, . . . which the system can use to store address pointers to entities. These are the normal means of referring to an entity between subroutine calls.
LEN = Entity number.
LT = Type of entity.
LR = Region number.

MD = Position of a word in the array holding the associative data in core store relative to beginning of array.
NA = Number of associative elements defined to be in entity of given type.
ND = Number of data words defined to be in entity of given type.
NS = Number of ring start elements defined to be in entity of given type.
N = Number of steps to be taken.
NOT = Number of steps not taken.
NEN = Number of entities.
NRG = Number of rings.

Creation and Deletion of Entities

DEFINE (LT, NA, NS, ND)
Define the number and type of elements in entities of type LT

CHAD (LT, ND)
Redefine the number of data words in entities of type LT

MAKE (LT, LR, LEN, KEA)
Create an entity of type LT in region LR. The number of the entity will be stored in LEN and its page/relative address will be stored in KEA.

FREE (KEA)
Return to the system the space which was occupied by the entity stored at the address in KEA.

Associative Links

PUT (KEA1, JS1, KEA2, JA2)
The element JA2 of the entity at KEA2 is inserted at the beginning of the ring starting at element JS1 of the entity at KEA1.

PUTEND (KEA1, JS1, KEA2, JA2)
As PUT but element JA2 of the entity at KEA2 is inserted at the end of the ring starting at element JS1 of the entity at KEA1.

SWOP (KEA1, JS1, KEA2, JA2, KEA3, JA3)
Interchange the element JA2 of the entity at KEA2 with the element JA3 of the entity at KEA3 in the ring starting at element JS1 of the entity at KEA1.

TAKE (KEA1, JS1, KEA2, JA2)
The element JA2 of the entity at KEA2 is removed from the ring starting at element JS1 of the entity at KEA1.

Movement in Rings

TYPSTP (LT, LR, KEA, N, NOT)
Take N steps round the entities of type LT in region LR from the entity at KEA and store in KEA the address of the entity so reached. If KEA=0 when the CALL is executed stepping will be from the ring start. (If the ring start is reached before the stepping is completed NOT is set to the number of steps not taken and KEA set to zero).

ENTSTP (KEA1, JS1, KEA2, JA2, N, NOT)
Take N steps from the entity at KEA2 element JA2 round the ring starting in element JS1 of the entity at KEA1. KEA2 becomes the address of the entity so reached and JA2 the number of the required associative element in that entity. If KEA2=0 at the CALL stepping is from the ringstart KEA1, JS1. (NOT and KEA2 as for TYPSTP).

RNGSTP (KEA1, JA1, KEA2, JS2, N, NOT)
Take N steps round the entities which start rings containing the associative element JA1 of the entity at KEA1 beginning from the element JS2 of the entity at KEA2. The address of the entity reached will be stored in KEA2 and JS2 will become the number of the required ring start element within that entity. If KEA2 is set to zero before the CALL stepping will be from the associative element itself. (NOT is set to the number of steps not taken if all the rings are found before stepping is completed and KEA2 is set to zero).

GET (LT, LR, LEN, KEA)
In KEA record the address of entity number LEN of type LT in region LR. (If there is no entity of this number and type in the region KEA will be set to −1).

Interrogation of Entities

INFO (KEA, LT, LR, LEN, ND)
Record the type, region, number and number of data words of the entity stored at the address in KEA in LT, LR, LEN and ND respectively.

RINGS (KEA, NA, NS)
Record the number of associative and ring start elements in the entity stored at KEA in NA and NS respectively.

ENDATA (KEA, JD, MD)
Record in MD the position in the page array of the JDth word of data of the entity stored at KEA.

ENTT (LT, LR, NEN)
Record in NEN the number of entities of type LT in region LR.

ENTR (KEA, JS, NEN)
Record in NEN the number of entities in the ring starting at element JS of the entity at KEA.

ENTA (KEA, JA, NRG)
Record in NRG the number of rings to which the element JA of the entity at KEA belongs.

Discussion of Subroutines

Each of the subroutines is used by treating it as a FORTRAN subroutine and calling it in the usual way. Up to 127 different configurations of entity may be defined for a particular application and any number of any type may be made as required in any of the 63 regions. For over a year the ring processing package has been in use in connection with a project for computer aided design and it has been found that the use of fixed size entities has helped rather than hindered this work. Occasionally, however, it is necessary to vary the number of words of data held in entities of a given type and this is done by calling CHAD before MAKE each time an entity of that type is made.

The address pointers KEA are used in nearly all the routines. These consist of a page and relative address which permit the recording of the address of any entity on the disc. These pointers are held as FORTRAN variables so there is no restriction on their numbers and they may be recorded or deleted according to the needs of the program.

The routine GET does not alter the pages through which it searches for the required entity and special provision has been made to speed up its operation. Successive pages read from the disc overwrite each other in core until the appropriate page is found and no pages are written back to the disc. The possibility of finding an entity, even though it is not in any ring defined by the user, is not usually provided in ring processors but has been found to be quite useful in the computer aided design project mentioned earlier.

Two routines enable entities to be placed at the beginning or end of a ring. The use of SWOP with appropriate FORTRAN programming permits an entity to be placed at any specified position in a ring without upsetting the alternation of the backward and ring start pointers. For example, the following puts the entity whose address is held in KEA2 into the ring starting at the entity whose address is held in KEA1 at a position in the ring *after* the entity whose address is held in KEAB (known to be in the ring).

```
  CALL PUT (KEA1, JS1, KEA2, JA2)
1 KEA3 = KEA2
  JA3 = JA2
  CALL ENTSTP (KEA1, JS1, KEA3, JA3, 1, NOT)
  CALL SWOP (KEA1, JS1, KEA3, JA3, KEA2, JA2)
  IF (KEA3. NE. KEAB) 1
```

There is a notable absence of what are usually called " GO ROUND " facilities. In fact these are unnecessary because any such facility may be built up by writing appropriate FORTRAN programs around the facilities available in the package. (Provision of some simple GO ROUND facilities was contemplated but examination of those provided in other work of this nature showed them to be of restricted application and it was preferred to keep the package as small as possible so that transfer to another computer would be simplified). To illustrate the ease with which FORTRAN programs may be written to carry out complex operations on data structures the subroutine shown on facing page carries out one of two different operations upon each entity of any ring structure starting at element JS in the entity whose address is held in KEA; which operation is executed depends upon whether or not the entity under consideration is in a ring starting elsewhere. The two different operations are named FUNCA and FUNCB respectively.

With the array dimension 20 as shown this routine operates on ring structures to a depth equal to 20 but of course this figure could easily be changed. The subroutine could have been written to operate recursively but this was not done because many FORTRAN IV compilers do not permit recursive subroutines. No other published ring structure package known to the authors permits the writing of such complex ring structure operations with such ease.

If the two functions are as follows:

```
SUBROUTINE FUNCA (KEA, JS, KE, JA)
CALL TAKE (KEA, JS, KE, JA)
CALL FREE (KE)
RETURN
END

SUBROUTINE FUNCB (KEA, JS, KE, JA)
CALL TAKE (KEA, JS, KE, JA)
RETURN
END
```

each entity of the ring structure starting in the element JS of the entity whose address is KEA will be deleted unless it is also a member of

another ring structure. For example if, in Fig. 4, KEA was the address of entity A and JS = 1 all the entities marked X would be deleted.

The subroutine ENDATA (KEA, JD, MD) gives the user access to the data part of the entity whose address is held in KEA by assigning to MD the position, in the array holding the associative data in the core store, of the JDth word of data in the entity. Data may be taken from the array by any legitimate FORTRAN statement and similarly may be put into the array (*i.e.* into the data part of the entity). It is the programmer's responsibility to ensure that such operations are carried out only within the data area of the entity, when it is in core at a known address, (using INFO if necessary).

```
      SUBROUTINE PEDOR (KEA,JS,FUNCA,FUNCB)
      EXTERNAL FUNCA,FUNCB
      DIMENSION KE(20),KRSE(20),KAE(20),NE(20),NRSE(20),NAE(20)
      M=1
      KE(1)=KEA
      KRSE(1)=JS
      NRSE(1)=1
      KAE(1)=0
C     FIND NUMBER OF ENTITIES IN RING
    1 CALL ENTR (KE(M),KRSE(M),NE(M))
C     TEST IF RING EMPTY
      IF (NE(M).EQ.0) 2
      M=M+1
      KE(M)=0
C     FIND NEXT ENTITY IN LOWER LEVEL
      CALL ENTSTP (KE(M-1),KRSE(M-1),KE(M),KAE(M),1,NR)
    7 CALL RINGS (KE(M),NAE(M),NRSE(M))
      N=NAE(M)
C     TEST IF ENTITY IS A MEMBER OF OTHER RINGS
      DO 5 I=1,N
      CALL ENTA (KE(M),I,MSR)
      IF (MSR.EQ.0)5
      IF ((I.EQ.KAE(M)).AND.(MSR.EQ.1)) 5
C     ENTITY IS MEMBER OF ANOTHER RING
      ASSIGN 11 TO L
      GOTO 8
    5 CONTINUE
C     TEST IF ALL RING STARTS HAVE BEEN CONSIDERED
      IF (NRSE(M).EQ.0) 3

      KRSE(M)=1
C     WORK ROUND NEXT RING
      GOTO 1

    2 NRSE(M)=NRSE(M)-1
C     JUMP IF ALL RING STARTS CONSIDERED
      IF (NRSE(M).EQ.0)4
      KRSE(M)=KRSE(M)+1
      GOTO 1

C     TEST IF ORIGINAL ENTITY REACHED
    4 IF (KE(M).NE.KEA) 3
      RETURN
C     ENTITY ONLY ATTACHED TO RING STARTING IN GIVEN ENTITY
    3 ASSIGN 10 TO L
    8 KTS=KE(M)
      KTA=KAE(M)
C     FIND NEXT ENTITY AT SAME LEVEL IF ANY
      NE(M-1)=NE(M-1)-1
      IF (NE(M-1).EQ.0) 9
      CALL ENTSTP(KE(M-1),KRSE(M-1),KE(M),KAE(M),1,NR)
    9 GOTO L,(10,11)
   10 CALL FUNCA(KE(M-1),KRSE(M-1),KTS,KTA)
      GOTO 12
   11 CALL FUNCB(KE(M-1),KRSE(M-1),KTS,KTA)
C     TEST IF OTHER ENTITIES AT SAME LEVEL
   12 IF (NE(M-1).NE.0) 7
      M=M-1
      GOTO 2
      END
```

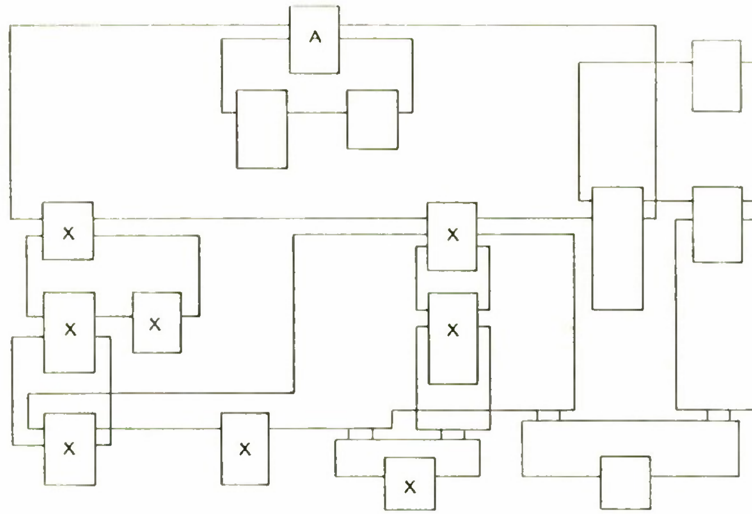

FIG. 4. To Illustrate Operation on a Complex Ring Structure.

The software also contains facilities for initiating the system, for error tracing, and for deleting or archiving complete data files. It is possible for one program to set up a data structure and for other programmes to run subsequently to alter the data in various ways. These facilities are described in the Users' Manual mentioned on page 218.

Compacting of Data

After operations on a ring structure involving the use of subroutine FREE there will, in general, be unoccupied spaces between entities on the pages. Although these spaces are used first, when entities are made, after a time the free spaces will gradually accumulate and the data will occupy more space than it needs. It is therefore necessary to have a routine for compacting the data into a smaller space. This is a time consuming operation because the entities must be moved and each time this happens all the pointers to the entity must be found and changed. It is therefore desirable to run the compacting routine only when it appears to be necessary rather than, say, at the end of each run of a program which changes the data. In order to discuss the operation of the compacting routine it is first necessary to describe in more detail the organisation of free space within the pages.

The first word on each page is an associative element in a ring of pages in a given region. The second word on each page holds the region (6 bits) and the number (11 bits) of words in the largest block of free spaces on that page and starts two rings through the first words of all the blocks of free space on the page. These rings consist of pointers comprising 11 bit addresses relative to the beginning of the page. One of the rings connects the blocks in order of increasing size and has only forward pointers. The other ring connects the blocks in the order in which they are found on the page and has forward and backward pointers. A further 11 bits in the first word of each free space block are used to indicate the number of words in the block.

When subroutine MAKE is called a search is made through active pages in the specified region for a page having a block of free words large enough to hold the new entity. The headers of pages of the required region that happen to be in the core store are examined first and only then is the search continued, if necessary, by reading pages from the disc. No alteration is made to a page if it has not enough free space so, to save time, successive pages read from the disc overwrite each other in the core store and none is written back to the disc. (The number of pages searched before claiming a new page may be specified by any particular applications program). If none of these pages has enough free space for the new entity a new page is taken from the ring of free pages in the region and put into the ring of active pages. When a suitable page is found the ring of free space in it is searched in order of increasing size. The smallest suitable block of free words is made into an entity and the rings of free space on the page are amended

accordingly. When subroutine PUT or PUTEND is called and it is necessary to create a knot there is a similar procedure, in the region of which the entity being put is a member, starting with the page holding that entity. Subroutine FREE simply replaces the entity header by the first word of a block of free space, sets the size of the block in this word, and inserts it into appropriate places in the rings of free space on the page.

The compacting routine is activated by calling either subroutine COMPAC or COMPRE (LR). It operates in two stages. In the first stage a number NC of pages to be used is specified. In general, considering each entity on the current page in turn, the compacting routine steps back NC pages through the ring of active pages in the region ignoring pages that are full. The entity or knot being considered is moved to this page if there is room for it and all the pointers in other entities or knots in rings of which it is a member are changed accordingly. If there is no room on a page the compacting routine steps forward to the next page (ignoring full pages) and continues to do so until the current page is reached. It then deals with the next entity or knot on the current page and so on until it has attempted to move all the entities from the current page to a vacant space on one of the NC pages before it. If the current page is completely free as a result of these operations it is thereafter excluded from the compacting operations by taking it from the ring of active pages in the region and putting it into the ring of free pages in the region. If not, the entities left on the page are moved to the top of the page and the remaining free space combined into one large block. The next page then becomes the current page for the compacting routine. If NC is set to zero the routine only compacts the entities within the current page itself and combines any separate free spaces in the page.

Each file on the disc contains blocks of pages. During the second stage of the compacting procedure a test is made to determine if it is possible to accommodate all the active pages in the region in less blocks than are currently allocated to it. If it is possible the active pages in the last n blocks, where n is the number of blocks no longer required, are moved onto the free pages in the earlier blocks. The file is then made smaller by n blocks. If the size of the file cannot be decreased the second stage of the compacting process is not carried out.

Comparison with other Similar Work

Ours is a ring processing package in which the construction of rings is automatically carried out and it cannot therefore be compared with low level packages such as L[6] (Gray 1967) with which the user creates his own rings from primitive building blocks, nor can it be compared with packages such as AED or those which use hash coding techniques. Our debt to the CORAL ring structure has already been mentioned. The only systems similar to ours and known to be in general use are APL (Dodd 1966) and ASP (Lang and Gray 1968) so attention will be confined to these two.

Both ASP and APL use only one type of entity to store data and the number of words of data in each entity (element in ASP) must be declared each time one is created. In most applications, however, many identical entities exist in a data structure and there are usually only a few distinct types each type having a different data length. This led us to arrange for the definition of up to 127 distinct entity types each having a fixed number of data words but to allow the number of words of data to be changed (by calling the CHAD sub-routine) before an entity is made if this is required. This has been found to be a convenient arrangement.

If we represented an ASP structure by means of our package each entity (ASP element) would have only one associative element and only one ring start element and an arbitrary amount of data. We would also need to define one other type of entity, with one data word for name and type, to represent the "ring starts" of ASP (let us call this a ring start entity). Our knots would correspond to the ASP associators except that in ASP there would be a knot even if the entity was only in one ring. Each time an ASP element (or entity in our terminology) was put in a ring to associate it with another element, a ring start and an associator (in our terminology a ring start entity and a knot) would have to be created and the address pointers between all four items would have to be set up. Fig. 5 shows the ASP structure corresponding to the one shown in Fig. 3. In Fig. 5 a triangle represents an ASP ring start and a circle represents an ASP associator. It is clear that ASP requires many more address pointers than our package,

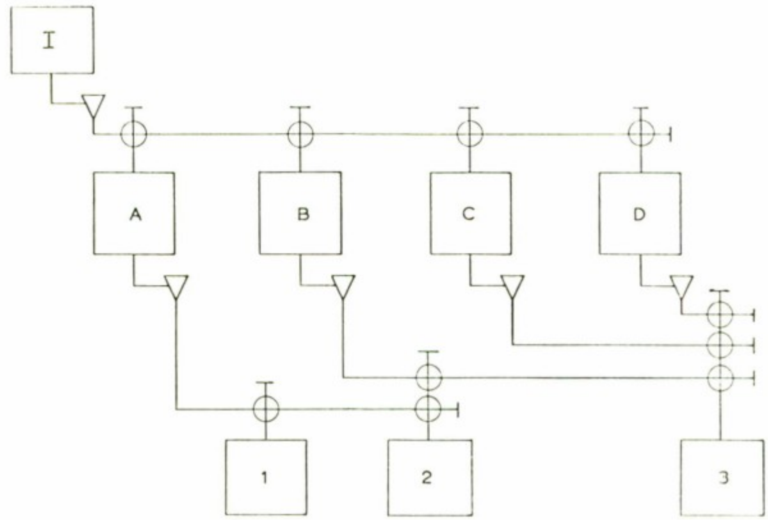

FIG. 5. ASP Ring Structure Corresponding to that in Fig. 3.

particularly for simple data structures, and the ASP ring starts and associators might be set up on different pages from those on which the elements they connect are placed. In practice, we have found that most data structures set up for computer aided design require only three or four rings (often only one) to start in each entity. This led us to restrict the total number of ring start and associative elements in a given entity to six so that, in the absence of ring start entities and with the provision of knots only when necessary, the data structures set up would occupy less space, and be processed more quickly, than with a package corresponding to ASP. (Should one require more ring starts than an entity can hold it is possible to use the equivalent of ring start entities to extend the number, as described above under the heading "Representation of Data Structure in Computer Store"). In this respect, therefore, our package resembles more closely the arrangement used by APL.

With our package an entity can be found (by GET or TYPSTP) even though it is not in any ring. This facility is not available in APL and in ASP an entity is automatically deleted if all its associations are removed.

APL statements are written into PL/1 programs and the programs must then be run as data for a preprocessor which outputs PL/1 statements and subroutine calls. This output can then be processed by a PL/1 compiler. With our package the FORTRAN (or other high level language) statements and subroutine calls are written directly, thus removing the need for a preprocessor (but certain other facilities provided by the APL preprocessor—not concerned with ring processing—are not present). This arrangement has been found to suit programmers already experienced with FORTRAN and some quite complex ring processing operations have been written. ASP runs with a compiler and has been implemented on Atlas II using the Mixed Language System available on that computer so that programs written in different languages may be compiled into a common format. Thus on that computer ASP commands could be embedded in programs written in a high level language, as in our system, but transfer to another computer would be more difficult. It appears that ASP has not been implemented with any backing store facilities.

Concluding Remarks

The package contains all the necessary basic subroutines to enable FORTRAN programs to include complex ring processing operations by use of the ordinary FORTRAN facilities. The paging software allows up to two million words on the KDF9 disc store to be directly addressed by FORTRAN programs. The package includes comprehensive facilities for compacting a data structure from which data has been deleted. It has been thoroughly tested and, as the routines became available in 1968, they have been used in a number of programs being developed for on-line computer aided design and the package is regarded as fully proved.

In different applications pages may differ in size from 40 words to 2048 words (but must of course be of constant size for a given data structure). A large page will be read from the disc in only slightly longer time than a small page but may bring with it more redundant information. The proper use of the regions to hold different parts of a data structure should, however, make the use of large pages comparatively efficient. It is intended to carry out studies of the effect of page size and the use of regions on the performance of the package in various circumstances. These studies will take some time and the results will be reported later.

The connection of the package to FORTRAN is via a number of short subroutines. These could very easily be rewritten to connect the package to another high level language such as ALGOL. The package, which took less than two man years to develop, has been kept as small as possible. (It occupies about 2000 words of KDF9 User Code and is not a compiler type program). It would not be difficult to have it rewritten to run on another computer and this is all that would be necessary to permit FORTRAN programs which include ring processing operations to be run on a computer other than the KDF9.

Acknowledgement The authors are grateful to the staff of the Computer Technology Department of the General Motors Corporation, Warren, near Detroit, for valuable discussions during a visit by one of the authors (IMY) to their Research Laboratories on 13th April, 1967.

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RESEARCH FIELDS IN PHYSICS

In collaboration with the Standing Conference of Professors of Physics, the Institute of Physics and the Physical Society has prepared what is believed to be a unique reference book on university research in physics.

" Research Fields in Physics at U.K. Universities " is a 350-page compendium of contributions from more than 60 University Departments. Each department has provided informative outlines of its research activities, with supplementary notes giving the composition of the research teams and the names of the senior staff concerned.

Beyond its role as a source book for potential research students and their advisers, this publication should prove of particular interest for many others requiring a compact but meaningful guide both to the physics specialisms in U.K. Universities and to key figures in specific fields. The contents will keep universities better informed on each other's activities, and assist industry and Government research laboratories to establish closer links with specialists in the physics departments. Those planning conferences in physics will also find this volume helpful.

There has only been a limited printing of this book. The majority of the copies have already been sold to the contributing university department, and the remaining stock is now almost gone.

Copies may be obtained from:

The Education Office, The Institute of Physics and The Physical Society, 47 Belgrave Square, London, S.W.1. Price 65/- (post free in U.K. and overseas via surface mail: Overseas airmail £1 extra).

TECHNICAL NOTES

Hydrophone System Measures Radiated Ship Noise

Admiralty Underwater Weapons Establishment

A new hydrophone system has been developed with significant improvements in acoustic properties, ruggedness and reliability compared with existing hydrophones.

The main elements of the system are the sinker assembly, main cable and shore end supply panel which incorporate some novel design features.

The function of the sinker assembly is to support the hydrophone element at the apex of a resilient rubber cone at a suitable height above the sea bed and to retain it in the same location. The sinker includes an amplifier which in addition to providing some voltage gain, gives the correct matching impedance to the main cable and to the hydrophone element, and incorporates means of calibration by the injection of known signals along the main cable.

The hydrophone element consists of a 22 mm diameter hollow sphere of lead zirconate titanate (LZT) piezo-electric ceramic. The two hemispheres from which the sphere is assembled are oppositely polarised and connected in series to increase the open-circuit hydrophone sensitivity. Resonant frequency of the hydrophone is in the region of 90 kHz and is omnidirectional at the low-frequency end of its operating range.

The amplifier is designed to accept signals in the frequency range 1 Hz to 100 kHz from a capacitance source of approximately 3000 pF to provide a stable voltage gain and drive a cable of 110 ohm characteristic impedance. It is constructed in the form of circular glass-reinforced plastic printed circuit cards for fitting into the amplifier pot.

The cable and all underwater fittings are designed to operate in water depths down to 1000 metres.

The main cable must pass the hydrophone output signals to the recording equipment ashore with minimum attenuation: cable noise must be low, and crosstalk between cores must be negligible. A special heavily armoured 6-core cable with polythene insulation meets these requirements, and its low attenuation at the highest operating frequency (80 kHz) enables the system to be used with sinker assemblies as far removed as 10 km (5·5 nautical miles). The hydrophone system is designed also to accept existing 4-core cables.

The supply panel acts as a link between the underwater hydrophone and amplifier system and the measuring equipment ashore. It provides suitable power supplies for the amplifier, and in the case of the 4-core cable systems, controls the battery charging and its switching arrangements. For the 6-core cable system separate pairs of cores are available for output, power supply, and calibration signals, while with the 4-core cable system NiCd rechargeable batteries are fitted in the amplifier pot so that the two cores of the cable normally used for supplying power may be used for a calibration signal when the batteries are not being charged.

Solid State Indicator Lamps

Services Electronics Research Laboratory

Two applications using solid state electronics — a panel indicator lamp, and a device which indicates visually the state of binary logic circuits — have been developed at this laboratory.

There are many situations in which a solid state lamp with its long life and high reliability would have considerable advantage over the tungsten filament lamps which are normally used as panel indicators. For such a device to have wide application it is desirable that it should provide a direct physical plug-in replacement for a tungsten filament lamp and operate from the same power supply.

A suitable lamp has been made by incorporating a gallium phosphide electroluminescent diode and a resistor within the dimensions of a standard sub-miniature indicator lamp. The device emits radiation in the red region of the spectrum and draws a current of 15 mA from a 4·5 V supply.

There has for some time been a need for an electronic device to indicate, visually, the state of binary logic circuits. Ideally it should be compatible with transistor circuitry and impose a negligible load when introduced into the logic circuit.

These requirements, which existing devices only partially satisfy, have been met by using a gallium phosphide electroluminescent diode in conjunction with a thick-film transistor drive circuit, the complete three-terminal device being encapsulated in a package with maximum dimensions of 0·2 in. (5 mm.). It is designed to operate from a logic circuit 5 V supply at 4 mA and indicate the logic state '0' (0·5 V, lamp off) and '1' (2·5 V, lamp on) with input currents of less than 5 μA and 30 μA respectively.

Automatic Switching Unit

Naval Construction Research Establishment

This unit, developed at this establishment, enables up to 12 fixed single-crystal probes to be connected in turn to an ultrasonic flaw detector. It is particularly useful when detecting the development of cracks in metal fatigue specimens, relieving the operator of the need to manually change from one detector probe to the next, and allowing full attention to be given to traces produced on the cathode-ray tube.

The unit operates from 240 V ac with a power consumption of 40 W. The circuit consists of a multivibrator of 0·5 Hz driving a 6 V relay, the contacts of which open and close a 48 V dc supply to the coil of a 25-way uniselector switch. This provides a two seconds pause on each channel to give sufficient time for each trace to be observed.

The circuit is energized by 9 V dc supplied from a full-wave bridge rectifier through a stabilizing circuit, with reference voltage obtained from a 9 V zener diode. A 48 V dc supply for the uniselector switch coil is obtained from a full-wave bridge rectifier, without smoothing.

On each of the switch positions from 1 - 12 the channel selected is indicated by a white lamp: on the remaining 13 switch positions a red lamp indicates that no channel is connected and the uniselector drives quickly to position 25. An auto/manual switch on the control panel enables a pause of more than two seconds to be made if it is desired to observe a particular trace for a longer period. In this case, the uniselector remains stationary until activated by a push switch. The signal lamps operate on 6·3 V ac.

A Probe for measuring Low Level Gamma Radiation and Beta Contamination

Admiralty Research Laboratory

A relatively simple probe has been developed which can measure the dose-rates from gamma or X-radiation between levels of 0·1 m rad/h to 1000 m rad/h with an accuracy of about $\pm 20\%$ between 80 and 1250 keV, using commercially available Geiger tubes and appropriate electronics.

When monitoring discrete areas of beta contamination having an activity of 0·1 μCi/sq. cm from day old fission products, an indication of about 10 m rad/h is obtainable. The monitoring of contamination levels of less than 0·1 μCi/sq. cm in the presence of low energy (below 75 keV) gamma radiation, is restricted to maximum background levels of about 20 m rad/h.

The instrument preserves a full scale reading even when the probe is irradiated by fields producing a dose-rate several orders greater than that of full scale and uniform calibration of meter scales is accomplished with a single variable pre-set control.

To minimise the probe weight and size, the instrument is in two parts consisting of the probe with integral meter joined by a flexible cable to a control unit containing the operating switches and power supplies.

The system is in four stages, pulse amplification, generation of uniform energy pulses, pulse integration and scale shaping, and a power supply unit. A test oscillator is built in for calibration and circuit testing. Audible presentation and a liquid counting assembly are also provided.

R.N. Engineering College—CONFERENCE ON NAVAL MATERIALS

By the Editor

The Captain and Staff of the Royal Naval Engineering College, Manadon (H.M.S. *Thunderer*), recently were organisers and hosts to a very successful residential Conference on the current and future problems surrounding naval materials, held from 3rd - 6th July.

The 200 delegates present were almost equally divided between the R.N., Industry, the Universities, the M.O.D. and its Establishments.

It is well known that the conditions with which ships, and particularly the Navy, have to contend, are often totally different to those of land practice and the aim of the Conference was to examine some of the unique Engineering/Materials problems involved and to throw light upon possible solutions from the results of current materials research.

Three specific areas were covered:—

(i) Structures, ferrous, non-ferrous and composite materials;
(ii) Machinery systems, and in particular the marine gas turbine;
(iii) Defect analysis and systems monitoring.

The content and academic level of the lectures were so arranged as to appeal to graduate engineers, metallurgists and material scientists and the event was well attended by some 150 representatives from the R.N., the Navy Department and its Research Establishments, the Research Associations, Industry and the Universities. In his address of welcome, Captain D. G. Satow, R.N., Captain-in-Charge of the College, referred to the fact that this was the first occasion that the College had organised a Conference of this nature and hoped that, whilst bringing together the experts in a particular field, with a view to fostering communication, the subject itself would derive benefit.

The Director General Ships, Vice Admiral R. G. Raper, in his opening address, presented a particularly comprehensive review of problems which have beset the R.N. in the past, are now facing the naval engineer and scientist and took a look into the future of naval engineering design in the light of the enhanced properties of the new materials now becoming available. In a recent analysis of repairs required to a particular Type 21 Frigate, Admiral Raper stated that some 40% had been put down to the effects of corrosion or the effects of its immediate by-products. He also hinted at the shape of things to come in the design of vessels with strange flat tops.

As might be expected at a gathering in connection with naval material science, a number of the speakers came from the R.N.S.S. Led by DMR(N), Mr. N. L. Parr, who traced the Origin and Growth of Materials Science in the Navy Department from the middle of the 19th century to its present position under functional management, after dinner on the second day and gave the final paper on Materials and Research Planning in the R.N., speakers came largely from the Admiralty Materials Laboratory; they were very ably supported by papers presented by specialists from the Central Dockyard Laboratory, Naval Construction Research Establishment, Director General Ships and the British Steel Corporation.

Whilst copies of some of the papers were made available to the delegates, it is understood that they will not be published as Proceedings, nor will any report be made of the extremely worthwhile discussions which took place after each paper. However, it is hoped to include some of the papers in future issues of *J.R.N.S.S.* but in the meantime the following brief abstracts will no doubt be of interest.

Review of Ferrous Metal Problems.

A. D. E. Thomson, R.N.S.S.

Naval Construction Research Establishment

This lecture reviewed the properties expected from present quenched and tempered low alloy high strength steels and projected what may be attainable for certain of these properties in future steels of even higher strength. The characteristics covered include:

(a) Yield to ultimate ratio indicating the margin of safety between yield point and ultimate failure.
(b) Notch toughness to prevent failure in a brittle manner.

(c) Resistance to failure under conditions of low cycle fatigue and the relationship of cyclic life to design ratio.

(d) Composition of the steel for the best compromise between the above conflicting requirements and at the same time afford good weldability.

(e) Acceptable degree of cleanness of the steel in thick plate form.

Emphasis was laid on the relative toughness of weld metal, heat affected zone and parent plate and the limitations imposed in heat input and preheat to minimise related hot and cold cracking.

Lamellar tearing is now a common mode of failure in highly restrained joints. Its cause, and methods of avoidance by good design, or selection of material was discussed along with the development of tests which it is hoped will define the sensitivity of material to this type of failure.

Current steelmaking practice was outlined and the conclusion drawn that as the tensile strength increases, the distribution of non-metallics must become one of the controlling factors in performance and therefore, to control them, more advanced methods of steelmaking may be required.

Steels for Structures.

J. Lessels, A.I.M.
British Steel Corporation

This paper indicated the availability of steel properties at present over the range of normal commercial materials, and those supplied in plate form for the specific requirements of naval construction.

Then followed a comment on the problems facing the steel manufacturer in progressing towards newer varieties with enhanced characteristics. It was considered that progress would be made in the consistency of properties from one delivery to the next, or even within an individual plate and greater attention given to standards of cleanness, composition and processing methods to reduce the problems of welding, the essential method of fabrication.

The application of non-detructive testing and its significance for the steelmaker was also discussed.

Cast Copper Alloys for Naval Applications.

J. N. Bradley, B.Sc., A.R.S.M., A.R.I.C., R.N.S.S.
J. M. Short, B.Sc.., A.I.M., R.N.S.S.
and L. Wortley, M.Met., F.I.M., R.N.S.S.

This paper covered the development, evaluation and use of copper alloys as castings and clad components in the sea water systems. The selection of a particular alloy is made on fitness of purpose based on its response to the service environment. Corrosion resistance is therefore, of paramount importance while other factors such as availability, castability, weldability, response to cyclic and dynamic stresses determine the specific application. For general service, gun metal castings are widely used whilst for applications where component failure could hazard the ship, the more readily weldable, strong, shock resistant alloys such as aluminium bronzes and cupro-nickels are in service.

High quality castings, continue to present problems. It is hoped these will be resolved by technological data now being acquired.

Welding and weld repair procedures for gun metal, aluminium bronzes and cupro-nickel alloys were discussed in particular to the effects on corrosion and metallurgical properties of castings.

Procedures were discussed for the manufacture of complex components by part fabrication in which cast and/or wrought cupro-nickel sub assemblies are welded. The alternative of cupro-nickel weld overlays on fracture tough steel to optimise corrosion and shock resistance was stressed.

A review of improved alloys now under evaluation was given.

Recent Applications of Glass Reinforced Plastics.

H. Gibbs, R.C.N.C.
Ship Department, M.O.D. (N)

Fibre reinforced composite materials have been known for many centuries but large scale industrial use is largely confined to the last three decades. Applications include radomes, fairings, boats, tanks, linings, *etc.*, but apart from highly sophisticated activities where weight saving may have priority the applications have been largely confined to relatively lightly loaded structures operating in hostile environments.

The potential strength of glass fibre is extremely high (UTS 230 tons per square inch, E $10{\cdot}5 \times 10^6$ p.s.i.) but the resin matrix has a UTS of only 2 - 6 tons p.s.i. and a tensile modulus of $0{\cdot}3 - 0{\cdot}5 \times 10^6$ p.s.i. The composite material reflects the combined properties and is further degraded by the processing of the fibres to provide a handleable product. The laminate properties will depend largely on the

glass content (25% - 80% by weight), continuity of fibres, fibre orientation and the fabrication technique.

M.O.D. (N) has now placed an order for a Minesweeper hull constructed wholly in this material. The ship will be approximately 50 metres long with a displacement of around 45 tons and will be the largest " plastic " ship afloat. The increase in size over existing boats involves highly stressed laminates and many problems not previously met in smaller structures.

As design concepts and production methods improve, rcinforced plastics are likcly to continue to supplant traditional materials for structural applications. Improved stiffness by the selective introduction of high modulus fibres may provide the necessary " bridge " to larger structures, but considerable additional knowledge is required before optimum use will be realised.

Fibre Reinforced Plastics.

R. Dukes, B.Sc., Ph.D., M.A.I.A.A., R.N.S.S.
Admiralty Materials Laboratory

Fibrc reinforced plastics in general have several unique characteristics, which set them apart from conventional structural materials. The major desirable factor is the possibility of achieving a high strength to weight ratio by the suitable arrangement of high strength fibres. Thc quality of such composite materials, measured by the precision of fibre alignment and the avoidance of voids, will have a great bearing on the final properties and the connection between quality and cost may impose limitations on the type which may be used in a given application. One can effectively design a composite for any given application—a novel situation for the designer.

Undcsirablc features such as inhomogeneity and overall anisotropy of most forms of construction and thc general brittle nature of the common matrix materials tend to be played down possibly due to lack of experience in designing structures in such materials. Lack of stiffness is often a handicap and small amounts of carbon fibres can have a significant effect.

Future improvements in the composites field were divided by the speaker into three areas.

(i) Improvments in fibre and matrix materials;
(ii) Improvement in design techniques for more efficient use.
(iii) Improvement of production techniques to lower cost and improve quality.

Structure Validation.

D. Birchon, B.Sc., F.I.M., C.Eng., F.I.Mech.E., M.I.Mar.E., R.N.S.S.
Admiralty Materials Laboratory

Structure validation is a process of proving the fitness of a structure to perform its required duties; it is therefore a positive approach to inspection.

An inspection policy geared to " inspection for defects " is intrinsically negative and can easily lead to heavy inspection expenditure and unnecessary repairs and delays a situation aggravated by the ever-increasing number of inspection devices and methods. The application of a policy of " inspect for defects " will not necessarily guarantee that harmful defects are detected, since faint indications of their presence (due to the use of an inspection technique not particularly suitable for their detection) can easily be lost against thc background clutter of trivial detail thrown up by the inspection process.

The author presented an inspection philosophy based upon the anticipation of a most likely failure mode, and thereby, the specification of both inspection techniques and the rejection criteria to be employed. This philosophy must also bring designer, matcrials engineers, inspectors and users together in a quantitative approach to which they can all make a contribution.

Materials in the Marine Gas Turbine.

J. F. G. Conde, B.Sc., F.I.M., R.N.S.S.
Admiralty Materials Laboratory

Gas turbines in the Royal Navy were reviewed briefly and Service experience which led to the decision to employ marinised aircraft gas generators for main propulsion machinery in new construction described. Materials for gas turbine plant were discusscd and the gencral problems of fatigue, creep, temperature limits and corrosion indicated in relation to the industrial gas turbine.

Problems which arisc in gas turbincs operating under shipboard conditions and when employing dieso fuel were discussed and compressor and turbine corrosion problems indicated. Measures already adopted to control the incidence of corrosion were detailed and potential techniques enumerated. Research and development aimed at introducing existing or newly developed materials likely to be more compatible with the marine environment. New directions for materials development were mentioned

in general terms. Current progress gives grounds for confidence in the future realibility of the marine gas turbine.

The Utilisation of Ceramics in Gas Turbine Engineering.

D. J. Godfrey, B.Sc., Ph.D., R.N.S.S.
Admiralty Materials Laboratory

High temperature strength and durability of ceramics are responsible for the interest in their use in gas turbine engineering. Silicon nitride is outstanding in its thermal stress and shock behaviour, because of its very low coefficient of thermal expansion.

It has a good combination of other properties, including hot strength, lightness, stiffness and oxidation resistance, whilst for a ceramic material its fabricability is exceptionally versatile. Precise shapes can be made easily by the machining of soft silicon compacts, which are subsequently reacted at high temperature to the hard strong ceramic without significant dimensional change. Recently developed processes use flame spraying or organic " dough-forming " binders to compact silicon powder, and give improvements in the capability to fabricate hollow or complex shapes. Large ceramic shapes can be fabricated with exceptional ease, and joints of high strength can be made by silicon deposit joining, advantages which are not enjoyed by most ceramic materials. Another form of the material, hot pressed fully dense Si_3N_4, though more difficult to fabricate, can show extremely high strength (1250 MN/m^2) and hardness.

Areas of application in gas turbines were surveyed, and included combustion structures, volutes and ducting, blades, afterburner and exhaust structures, heat exchanger components and bearings. Experience with silicon nitride materials in environments simulating that of the gas turbine were described. The possibility of combating engineering problems of brittleness by design were reviewed. The promise of composite materials, in particular, silicon nitride reinforced with silicon carbide continuous filaments, was discussed, and the encouraging prospects for tougher ceramics described.

Monitoring Machinery Health

D. Birchon, B.Sc., F.I.M., C.Eng., F.I.Mech.E., M.I.Mar.E., R.N.S.S.
Admiralty Materials Laboratory

Gas turbines for marine propulsion are based upon aircraft engineering practice, where weight penalties ensure rigorous steps to trim design allowances and exploit materials and manufacturing process opportunities. " Marinisation " for a longer operating life under sea-going conditions has provided opportunities for incorporating modifications to facilitate inspection of critical areas.

Gas turbines are amenable to inspection methods which look at " overall " effects such as vibration levels and lubricating oil pollution. Inspection is linked to the maintenance philosophy which is coloured by the advantages and relative ease of unit replacement rather than refit in place. Spectrometric oil analysis programmes (SOAP) have been used with spectacular success in the operation of naval aircraft, and show the full potential of this technique. Less sophisticated and rigorous techniques are being developed for the problems of shipborne gas turbines, which will sometimes lend themselves to inspection by magnetic plugs. These plugs will detect ferromagnetic matter swept over their surface (whereas SOAP monitors wear debris in solution/suspension in the oil), but individual wear particles can indicate whether they come from ball or roller bearings, and, it is even possible to define the particular bearing which is wearing out.

Vibration analysis is another subject with a two-pronged approach based upon the development and provision of simple health monitoring maintenance aids, backed up by sophisticated analytical instruments.

In his summing-up Mr. D. Stewart Watson, Deputy Chief Scientist (R.N.) congratulated both the R.N.E.C. on their initiative in organising the Conference and the individual speakers for the very high quality and presentation of their papers. He felt, as did all those present, that this Conference on the State of the Art had proved so successful that it should be considered for other fields also.

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Portsmouth Symposium— DEEP SEA TRAWLER SAFETY

Reported by P. G. Williams, L.I.M., A.I.Inf.Sc., R.N.S.S.
Naval Scientific and Technical Information Centre

Resulting from the loss of three trawlers in Arctic Waters early in 1968 the Board of Trade set up a committee to investigate the safety of deep sea trawlers.

The Final Report of the Committee of Inquiry into Trawler Safety under the chairmanship of Admiral Sir Deric Holland-Martin included the following recommendation:

" The Ministry of Defence should be invited to make available as much information as possible on the armed forces' experience in keeping electronic equipment working under icing conditions."

Accordingly a Symposium was held at the Admiralty Surface Weapons Establishment and the Admiralty Experiment Works on 23rd June 1970. This was attended by representatives from the British Fishing Industry, Ministry of Defence (Navy Department), Marine Division of the Board of Trade, British Aircraft Corporation Ltd. and the Meteorological Office.

The object of the Symposium was, primarily, to make available the results of Naval Research on de-icing of radar and communication aerials. A broad view of the recommendation of the Holland-Martin Committee was however taken and the scope of the meeting was extended to include small ship operation, sea-keeping and habitability.

After the visitors were welcomed to A.S.W.E. by the Director, Mr. H. W. Pout, the meeting opened with a general paper on " Ice Accretion of Ships " presented by Instructor Commander D. J. Dacam, D.M.O.S.(N).

Mr. G. Thomson, Senior Ship Surveyor at the Board of Trade then presented two papers. The first, " Icing and De-icing of Distant Water Trawlers " described the effects of superstructure icing on ship stability and emphasised the steps which can be taken when designing trawlers. The second paper " Model Testing " described work carried out, using moored trawler models, at the National Physical Laboratory, Ship Division.

Mr. D. P. Smith, Meteorological Office, presented a film which showed the support work of the mother ship *Orsino* during the winter of 1968 - 69 in the Icelandic fishing grounds.

Mr. H. L. H. Ward and Mr. V. C. Petherick of A.S.W.E. gave papers on " Icing and De-icing of Radar Aerials " and " Icing on Radar and Communication Aerials ". The effect of ice and slush on aerials and antennae was described. The use of inflatable envelopes to remove ice was illustrated.

Mr. F. Corben of A.E.L. described work carried out on electrically heated windows and on the development of mechanical windscreen wipers for use in icing conditions. The use of the A.E.L. acoustic cladding for noise reduction of ships' diesel engines and its effects upon habitability was described and illustrated.

The Chairman for the morning session was Dr. D. G. Kiely of A.S.W.E.

In the afternoon the party transferred to A.E.W. where they were welcomed by the Deputy Superintendent, Mr. E. P. Lover, who acted as Chairman for the Session.

Mr. R. K. Burcher of A.E.W. presented a paper on the " Manoeuvring of Small Ships at Slow Speed " and Mr. J. E. Conolly, Chief Scientist, A.E.W., gave a brief talk on " Seakeeping ". Visitors were then shown the experimental facilities at the Establishment when model manoeuvring in calm water and in waves was demonstrated. Finally a discussion on the day's proceedings was held.

The Symposium provided a useful facility for the promotion and exchange of information between the Navy Department and trawler operation and maintenance organizations drawn from the distant water fleets at Aberdeen, Fleetwood, Grimsby, Hull and North Shields.

The papers presented and the ensuing and final discussions have been recorded. It is intended that the Proceedings of the Symposium will be reproduced and made available in due course.

Application for copies should be made to the Naval Scientific and Technical Information Centre.

R.N.S.S. IN *DEEP QUEST* SURVEY

The research submarine *Deep Quest* recently started a 20 dive ocean bottom survey for the U.S. Navy off Southern California's coast. The orange and white deep-diving vessel is to conduct a 10 dive operation to examine a 1,500 ft. square area in the Santa Barbara Channel and survey a 15 mile cable route.

One of the four man crew of *Deep Quest* is K. R. Haigh, a member of the R.N.S.S. at the Admiralty Underwater Weapons Establishment, Portland. During these surveys the vessel dived to 6,000 ft. The photograph shows Kenneth Haigh closing the hatch of *Deep Quest*.

A major Navy objective in the 20 dive mission is to demonstrate the surveying capability of a completely instrumented manned submersible. Information gathered from *Deep Quest* operations during the dives will also help the U.S. Navy refine operating techniques for underwater surveys. The square site was proposed for the Naval Civil Engineering Laboratory's experimental Seacon habitat. The Seacon Project was proposed by the Laboratory to investigate methods and tools for sea floor construction.

The site is under 600 ft of water, and the cable route to be surveyed stretches from a point 6,500 ft underwater shoreward. Working under a contract with the Naval Oceanographic Office, *Deep Quest* is provided with a sub-bottom profiler, sidescan sonar and a camera system to augment the vessel's normal operating systems. *Deep Quest's* maximum operating depth was listed at 8,310 ft.

Lockheed's doppler sonar navigation system and *Deep Quest's* tracking system will be the primary surveying elements for the route survey. Information from the site survey will directly support the Seacon Project, while the area selected for the cable survey is not of immediate importance to the Navy. However, the techniques for the cable survey would " prove useful in future surveys ".

NOTES AND NEWS

Senior Psychologist Department

Mr. A. C. Goodwin, Principal Psychologist has been appointed Acting Senior Principal Psychologist, succeeding Dr. N. A. B. Wilson who has transferred to the Ministry of Employment and Productivity.

Admiralty Compass Observatory

Dr. W. W. Jackson has left A.C.O. on his second " retirement " to undertake pay research work for the Civil Service Department.

Mr. G. J. R. Rosevear has joined the Observatory from D.N.R.D.A.

Mr. H. B. Hewitson (George) has retired after 30 years service at A.C.O.

In his early days he was engaged in gyro compass ship fitting, before forming an electronics section which he led for many years. This group designed many of the amplifiers and assoeiated instrumentation used with gyro and magnetic compasses.

Later, as an S.E.O. he beeame deputy leader of the gyro compass development section.

Among his attainments was an award of £1,000—no mean sum in 1950—for designing the small 2-phase A.C. motor AP 8064, a design later widely used by the Serviees and exploited by industry.

George was at one time an enthusiastic radio Ham and operated a station at A.C.O. in association with the late Alfred Hine.

At his farewell presentation he received a cheque from the Director, Captain T. D. Ross, R.N., subscribed to by George's A.C.O. eolleagues. This was followed by a brief speech of thanks for his gift and for the good wishes expressed to him.

Although he has eschewed the publicity normally accorded in retirement columns of *J.R.N.S.S.*, it is thought right at least to inelude a few notes reeording some of his aetivities and paying tribute to his long period of service to A.C.O. and to the Navy.

The Controller, Vice Admiral Sir Michael Pollock, K.C.B., M.V.O., D.S.C., accompanied by D.G.S., D.G.W. and senior members of their staffs, visited A.C.O. during April. In the course of their visit, the party toured laboratories and workshops and held technical discussions with members of the establishment.

Mr. H. J. Elwertowski, Chief Scientist, accompanied by Mr. E. Hoy of A.C.O., together with Mr. R. Holland (A.S.W.E.), Mr. J. Stringer (R.A.E.) and Cdr. J. Slocock (D.N.W. London) visited Washington during April to discuss international eo-operation on the OMEGA project.

OMEGA is a V.L.F. radio navigation system. expected by the end of 1972 to provide world-wide navigational data to accuracies of one to two nautical miles.

The system is expected ultimately to be controlled by an international civilian organisation and is intended for both eivil and military, sea and air use.

Mr. V. Hardy and Mr. J. Smith are visiting Cape Kennedy during May in connection with the Demonstration and Shake-Down Operation (D.A.S.O.) of H.M.S. *Revenge*, the fourth British Polaris submarine, whieh will be test-firing Polaris missiles.

The A.C.O. team has developed the heading calibration system used. This system is used to make an accurate transfer of a true bearing reference from a shore facility to a submarine at dockside.

The third Anglo/American gas bearing conference, sponsored jointly by A.C.O. and the U.S. Office of Naval Research was held during April at the Observatory. Delegates from both countries voted the gathering highly successful, and it is intended that this activity shall eontinue.

Admiralty Underwater Weapons Establishment

Nine members of A.U.W.E., with a similar number from the U.S. Naval Ordnance Laboratory, carried out a joint U.K./U.S. degaussing trial at St. Croix in the Virgin Islands during February. After a number of teething troubles had been overcome, work proceeded well and the trial was generally successful.

St. Croix, discovered by Columbus in 1493, has existed under seven flags, British 1801 - 1802 and 1807 - 1815. It is an island of contrasts; eastern end arid and rocky with cacti and scrub, western end lushly tropical with mahogany forests, mango trees, palm, etc., and in between, rolling hills, pastures and flat sweeps of sugar cane fields. Needless to say the U.K. team found the opportunity of spending some time on this tropical island in the Caribbean a very interesting experience and a welcome break from the British winter.

The Admiralty Experimental Diving Unit in H.M.S. *Vernon* has now become fully integrated in the A.U.W.E. as an outstation section of the Mine Countermeasures Division. The unit was represented at the Oceanology 1969 conference at Brighton in February 1969, exhibited and demonstrated at the MOD(N) sales week in May, attending the Symposium at the Commonwealth Club and exhibition at the R.M.R. Centre, White City.

Co-operating with the Superintendent of Diving, Information Exchange Project B12, on Diving Equipment has been re-activated with the U.S. Navy. Mr. R. P. Common, Officer-in-Charge A.E.D.U. and Commander P. A. White, S. of D., attended the first meeting at San Diego in December 1968. A strong U.S. Navy team visited the A.E.D.U. in May 1969 for the return meeting. Mr. Common and Cdr. White were also present at the Battelle Columbus 1970 Symposium "Equipment for the working diver" in Ohio in February and will again represent A.U.W.E. (A.E.D.U.) at the 1970 I.E.P. B12 meeting in June. Considerable information is being obtained on the great amount of R. & D. in advanced and deep diving techniques and equipment, and valuable personal contacts are being established. As the interface between A.U.W.E. and A.E.D.U. became more firmly established a certain number of staff moves were arranged to provide a measure of "cross fertilisation" and to ensure that diving R. & D. tasks were placed in the division best suited to deal with them. Numerous contacts have been made between the unit and industry, C.I.R.I.A., Min. Tech., M.A.T.S.U. and N.R.D.C., as part of the informal integration of diving R. & D. effort now taking place in the U.K.

Dr. E. J. Risness, S.P.S.O., has left for the Imperial Defence Course and his place as Head of the Sonar Research Division has been taken by Mr. A. Monk, S.P.S.O., who has just completed that course.

Dr. F. M. V. Flint, S.P.S.O., has left A.U.W.E. to take up appointment as Scientific Adviser to C.B.N.S. Washington.

Lieutenant Terry Tomkins, M.B.E., R.N. (Rtd.), of the A.E.D.U., finally left the service on 2nd March, 1970, after 25 years with the unit, and Lieutenant George Alpress, R.N. (Retd.), also of A.E.D.U. retired, aged 60 after 14 years.

Mr. James Hayes, retired recently at A.U.W.E. after 39½ years' service in Admiralty establishments.

Mr. Hayes joined H.M.S. *Osprey's* Experimental Department in 1930, and in 1932 made a transatlantic trip in the survey ship H.M.S. *Challenger* in connection with the early echo sounders. He spent two years at the R.N. Cordite Factory, Holton Heath, returning to Portland in 1937. Most of the war years were spent in the Mediterranean and the Middle East, finishing with a temporary commission in the R.N.V.R., and a spell in Ceylon. He returned to Scotland in 1945, and came back with the Establishment to Portland in 1946.

Mr. Hayes will continue to live in Weymouth, and will now be able to concentrate on his many activities, which include scouting, sailing, the drama club, and the Arts Centre.

The photograph shows Mr. Hayes (right) receiving a cheque from Mr. W. K. Grimley, head of Sonar Department, who presented it on behalf of his many friends and colleagues at A.U.W.E.

A pleasant ceremony took place in A.U.W.E. on 19th March when Deeds of Apprenticeship for 20 apprentices were signed. After the signing, their parents were given a conducted tour of workshops, including the Apprentices Training Centre. Before their departure, the parents had an informal meeting with staff over tea in the Principal Officers' Mess.

Central Dockyard Laboratory

Mr. Stewart-Watson, D.C.S.(N) accompanied by Mr. N. L. Parr, D.M.R.(N) visited the Central Dockyard Laboratory on 23rd March, 1970 and met many members of the staff during his tour of Sections in the Main Laboratory and the Exposure Trials Station at Eastney.

The visitors accompanied by the Superintending Scientist and his Deputy were entertained to lunch by the Flag Officer Spithead, Rear Admiral A. M. Power, R.N., M.B.E.

Mr. J. C. Rowlands gave a lecture on "Corrosion in Ships' Sea Water Systems" during a Marine Corrosion Symposium at the Society of Chemical Industry, London, on 14th April, 1970.

Mr. B. N. Hall presented a paper on "Corrosion of Metals in Sea Water" at the Spring Symposium of the Yacht Brokers, Designers and Surveyors Association held at the University of Southampton on 3rd April, 1970.

David A. Hudson retired from C.D.L. on 16th February, 1970 after serving nearly 40 years with the department. To mark the occasion the Superintending Scientist (Dr. E. N. Dodd) presented him with a clock on behalf of his colleagues.

After obtaining the Associateship of the Royal Institute of Chemistry at Leeds College of Technology, David Hudson joined the Admiralty Chemist Department in November 1930 in a temporary post advertised as lasting approximately six weeks. After serving in the rubber, oil and paints sections of Admiralty Chemist Department he was transferred to the R.N. Mine Depot at Milford Haven in December 1940 where he was in charge of the laboratory and remained there for the duration of the war.

On his return to Portsmouth in September 1945, he specialised in the preservation of ropes, textiles and timbers and gained promotion to Senior Experimental Officer in January 1951. He was subsequently in charge of the section of the laboratory dealing with Fleet support, general materials and gas analysis.

Apart from the very diverse field of activity in this area of work, environmental safety in ship, workshops, offices and building sites was also of special concern. He was a founder member of the submarine Air Purification Committee and played a prominent part in the development of solid state oxygen for use in submarines.

Being keen on food, wine, and continental travel, David's retirement started with a Spring Cruise to the Canaries, a forerunner no doubt of many happy travels especially now that restriction on his time and foreign currency have been relaxed. His colleagues at C.D.L. wish David and his wife Beryl many happy tours of discovery in his retirement.

Mr. P. W. Moger attended the 8th Annual Conference on Adhesion and Adhesives at the City University, London, on 19th and 20th March, 1970.

Mr. W. R. Weaver won the Navy Department Championship at the Civil Service Rifle Association smallbore meeting at Hendon on May 2nd - 3rd.

Services Electronics Research Laboratory

Dr. D. C. Tyte and Mr. A. Crocker visited the G.C.E. Laboratories in Paris on 9th - 10th February to see and discuss work on high pressure, pulsed carbon dioxide lasers.

Messrs. D. M. Clunie, C. C. Pearce and B. C. Monahan attended a seminar on High Frequency Circuit Design and Microwave Components at the Royal Lancaster Hotel on 4th March, 1970.

Mr. G. P. Wright was appointed Deputy Director S.E.R.L. on April 20th, 1970.

Dr. R. M. Allen presented a paper entitled "Correlation of Electron Microscope Studies with the Electrical Properties of Boron Implanted Silicon" at the International Conference on Ion Implantation in Semiconductors, which took place at 1000 Oaks, Los Angeles, May 2nd to 16th.

At a Colloquium on Avalanche Diodes at the I.E.E. London on May 18th, Mr. P. Brook read a paper "Physical Limits on Large Signal Operation of IMPATT Diodes" by Mr. K. G. Hambleton and himself, and Mr. A. M. Wallace read a paper "Some Aspects of Copper-bonded IMPATT Technology" written in collaboration with Mrs. V. K. Webber.

A paper "Sealed-Off Neutron Tubes", by Messrs. J. D. L. H. Wood, D. S. Start and P. D. Lomer, was read by Mr. Wood at a symposium on "The Operation and Use of Low Energy Accelerators" at the Borough Polytechnic May 27th to 29th.

Members of the Herts Association of Special Libraries met at S.E.R.L. on June 3rd when the work of the Laboratory was described and demonstrated.

Mr. D. W. Downton visited the Netherlands in June to attend a Conference on the Fundamental and Practical Aspects of the Application of Fast Neutrons in Clinical Radiography, which took place at the Radiobiological Institute of the Organization for Health Research.

A paper by Mrs. V. K. Webber and Messrs. D. M. Clunie and A. M. Wallace, entitled "The Physical Structure and Microwave Performance of Copper-bonded IMPATT Diodes" was presented by Mr. Clunie at the Device Research Conference, University of Washington, Seattle, June 23rd to July 10th.

Mr. M. J. Beesley attended an International Symposium on the Applications of Holography at the University of Besancon, France, July 5th to 11th, where he read a paper "Some Experimental Techniques for the Recording of Diffraction Gratings in Photoresist".

Dr. D. C. Tyte visited Canada from 12 - 17th April in order to visit various Establishments concerned with the research and development of carbon dioxide lasers.

Messrs. K. R. Heath and J. C. Vokes attended the "Skynet" Colloquium at the I.E.E. London on 20th April, 1970.

Mr. B. R. Holeman and Dr. R. G. F. Taylor presented invited papers at a symposium at R.R.E. Malvern on Pyroelectric Detectors and Imaging.

Messrs. B. T. Hughes and J. Pollard attended a C.V.D. Symposium on "The Design and Use of Non-magnetic Gas Analysers" at the Zoological Society, London on 5th March, 1970. Mr. J. Pollard participated in the organization of the symposium and acted as chairman.

Mrs. V. K. Webber attended a Stereoscan Operator Training Course during the period 8th - 10th April.

Colin Beaumont, who has for many years been in charge of the scientific glassworking services at S.E.R.L., Baldock, retired from the R.N.S.S. on 28th February, 1970, having worked for the Admiralty for over 30 years.

He joined A.S.E. at Portsmouth in January, 1940 and after transferring to A.S.E. Bristol in 1944, was one of the "founder members" of the Services Electronics Research Laboratory when it was set up at Baldock in 1945.

Throughout his career, Colin Beaumont made many valuable contributions to the research and development of vacuum tubes and related devices by his skill and versatility in constructing intricate and specialized scientific glassware and in doing his utmost to satisfy the demanding requirements of the laboratory. His services to S.E.R.L. and the R.N.S.S. were officially recognized on two occasions, by the award of the Coronation Medal and the Imperial Service Medal.

Many recall with pleasure Colin's prowess as a bowler on the cricket field when he was a mainstay of the S.E.R.L. team. He has also participated widely in other sporting and social activities of the laboratory.

The occasion of his retirement was marked by the presentation to him, by Mr. G. P. Wright on behalf of Colin's many friends and colleagues, of a transistor radio and pewter tankard (Colin is on left of photograph).

BOOK REVIEWS

The Use of Radar at Sea. Institute of Navigation. Pp. xiv + 280. Fourth Revised Edition. London; Hollis and Carter, 1968. Price 70s.

"The Use of Radar at Sea" is now a well established book. Since its original publication in 1952, there have been three new editions. With the new editions the opportunity has been taken to correct and revise the text. This is certainly true of the fourth revised edition, and the opportunity is taken to bring to the fore the problem of collision avoidance and the "Rules of the Road". Nevertheless the general plan of the book has remained unaltered.

Although the original foreword and preface have been retained, there is also a new preface for this edition. The book opens with a chapter on "Radar Principles and General Characteristics", which although assuming little or no knowledge of electronics is nevertheless a very interesting introduction for any reader. It is however a pity that the sine waves of Figure 2 have not been drawn more carefully, but this is a minor criticism. The second chapter describes the radar equipment itself. This chapter is mainly descriptive, and the advantages and possible disadvantages of various solutions are not always discussed, e.g. change of squint angle with frequency for slotted arrays. One has the impression that this chapter has been carefully planned to bring the uninitiated quickly yet gently to the next rung of the ladder. The chapter closes with the performance monitor with particular emphasis quite rightly on the common method in use i.e. the echo box. It is felt that the opportunity could well have been taken here (if not elsewhere in the book), to discuss the coarseness of this device; although the performance check detailed in the appendix on the Marine Radar Specification may give the reader a clue to its relative accuracy. Chapter 3 discusses in detail the operational controls of the marine radar.

The book now continues with four chapters covering the propagation of waves, response of targets, radar meteorology, display interpretation, and unwanted echoes and effects. Seventy pages are taken and the subjects are covered very well and very fully. Once again, little basic knowledge is assumed and each subject is rapidly developed for the enthusiastic user, while covering a multitude of points of interest to the engineer and physicist. It is a pity that P50 is marred by a printing error when 0 miles is printed instead of 0·25 miles. These chapters are well illustrated not only with figures, but also with excellent plates of which the book has 52.

Chapters 8, 9, and 10 cover Radar as an Aid to Navigation, Radar for Collision Avoidance, and Radar and the Rule of the Road at Sea. The title of Chapter 10 is wrongly printed in a way which many readers would fail to notice. These chapters are very comprehensive and contain numerous charts and examples. Common sense is well to the fore, caution is sensibly stressed throughout, and every marine radar user would be well advised to read and digest these chapters, which stress that radar does not solve the navigator's problem, but rather that it provides evidence of evaluation.

The next four chapters cover corner reflectors, ramarks and racons, shore-based radar, the keeping of records, and simple maintenance complete with a fault list.

Chapter 15 briefly introduces some of the elementals of ship system engineering, while Chapter 16 expands a little more technically on the subject matter of Chapter 2, and will enable the mariner to understand the nature of faults and how they occur.

The last chapter, Radar in the Future, runs through both the short term and long term development possibilities, reminding the reader nevertheless that marine radar is a very cost conscious market.

The five appendices cover Echo Recognition, the 1968 Marine Radar Performance Specification, Useful Test Equipment, a Glossary of Terms, and Constants, Formulae, and Useful Data.

The book is well indexed, and is very well printed on excellent paper. Every navigator should certainly own a copy, and all radar engineers who are interested in or concerned with radar at sea should be acquainted with its contents.

P. Andrews

Flow in Channels. By R. H. J. Sellin. Pp. ix + 149. London; Macmillan and Co. Ltd. 1969. Price 55s.

This volume serves two groups, the practising hydraulics engineer and the advanced student. Since this is not intended as a complete treatise on the subject, considerable use has been made of references selected on two criteria: they either describe important work or thinking on the topic or they refer to more complete treatments of the subject. A very comprehensive bibliography at the end of the volume points out the fact that this is intended to lead the reader into the subject. The intention is well executed in six sections dealing in turn with uniform, gradual and rapidly varying flows, control and measurement, flow in erodible materials and finally unsteady flow in open channels.

The treatment is mathematical in nature and numerous diagrams help the text but the author does not hide the fact that problems are often solved by emperical means. In the reviewer's opinion this book goes a long way, small though it may be, to help fill the large gap that often exists between the river engineer's needs and the tools available to him. It might also bring home to the student that real life problems do not always have neatly packaged solutions.

D. P. Valler

An Outline of Polymer Chemistry. By J. A. Allen. Pp. vii + 136. First Edition. Edinburgh; Oliver and Boyd, 1968. Price 7s. 6d.

This book is written with the aim of reaching two groups of readers. The first group are the undergraduates who, while not studying polymer chemistry, wish to familiarise themselves with the elementals of synthetic polymers. The second group includes science teachers and non-specialist industrialists who want to acquire some knowledge of the subject fairly painlessly.

The book has eight chapters, which would appear to divide naturally into two parts. One part, the first four chapters, discusses the mechanism of polymerisation and only occasionally are specific polymers referred to. After briefly covering the molecular nature of polymers some of the nomenclature of the subject is explained. The different processes of polymerisation are discussed from condensation through addition to copolymerisation. This is followed by what is largely the physics of polymers in the solid state and in solution. The first half of the book while being very relevant to the science teacher, undergraduates with a leaning towards physics, and also to grammar school sixth formers, would probably be a bit boring to the average industrial non-specialist.

The second half of the book changes in outlook and many of the plastics in use today are discussed. Methods of manufacture, properties and principal uses are discussed, and in particular the variations throughout several families of plastics are pointed out. This part of the book is divided into four chapters which cover Vinyl and related polymers, Synthetic Rubbers, the Thermosetting Resins, and the Polyesters and Polyamides which are used particularly as fibres. Certainly the average non-specialist in industry would find this part of the book of particular interest.

The writing of a book of this level is always a difficult task and Professor Allen has tackled the task extremely well. The short bibliography has been carefully selected to give a maximum coverage of many aspects for further and more advanced reading. There is also a good index.

If a comment can be made of this book it is that it would be even better value if there were an additional chapter on some of the interesting work now being carried out in the field of high temperature plastics. Nevertheless this book is extremely good value, and should prove popular, particularly to the non-specialist user of plastics.

P. Andrews

Principles of Statistical Techniques. By P. G. Moore. Pp. viii + 286. Cambridge University Press, 1969. Price 45s.

The literature on statistical techniques is enormous and grows daily. My own experience, which I suspect is commonplace, is one of hours spent pouring through voluminous texts in public and government libraries and bookshops, none of which ever resulted in a successful search for just the right book to satisfy my requirements. I have found books where the mathematics is overwhelming, books with examples and no answers, and books in which the subject selection leaves much to be desired.

No such criticism can be levelled at this particular book. The aims are modest and clearly defined as an attempt to illustrate the

main principles of statistical method to those who are fundamentally concerned with the practical application of the subject.

This seems to me to be a worthwhile aim and I feel fits the need for many who rarely if ever have either the time or the desire to acquaint themselves with the philosophical and fundamental mathematical basis of statistical techniques.

The level of mathematics required is "O" level G.C.E. with a few exceptions. The author considers it suitable for a year course at a university for non-mathematical specialists.

The book is set out in 16 chapters and includes discussion on the collection, tabulation and presentation of data, frequency distributions, probability, tests of significance, sampling, regression, correlation and time series.

There are numerous worked examples, and further examples with answers at the end of each chapter. The presentation is clear and concise.

It might be argued that it covers little new ground that cannot already be found in a book such as Moroney's "Facts from Figures". However, although the price is somewhat excessive I believe that this modest volume is well worthy of consideration by those who must collect and interpret data as a subsidiary part of their professional lives.

P. F. C. Griffiths

Advanced Level Applied Mathematics. Pp. xi + 449. London. The English Universities Press Limited. 2nd Edition, 1969. Price 28s.

Since its first appearance in 1953, this book underwent eight impressions in its first edition, before its current appearance, as a second edition, in a revised form. This at once evinces its popularity, and in particular its usefulness for "A" level students, who in company with their teachers and parents, are desperately trying to keep pace with an ever changing syllabus. This does not mean that syllabus change is necessarily detrimental, but the tendency nowadays is to broaden mathematical syllabi at all levels, by introducing concepts that at one time were considered to be too advanced for G.C.E. (or equivalent) candidates. (For instance, many readers of this review, who are mellow in years, will doubtless recall that Vectors were not encountered until the latter stages of a degree course in their undergraduate days, or even in post graduate work).

The first edition of this book has already been reviewed in the *Journal*, and its particular usefulness to "A" level candidates was commented on most favourably. Dr. Lambe has, in his second edition, made changes to cope not only with current changes of syllabi, but also with proposed changes. The only omission from the first edition is a short chapter on compressible fluids, but this has given way to a new chapter on Mathematical Methods, a chapter which makes an excellent stepping stone to the first year of a graduate course. Several exercises have been adjusted to accommodate the move to metric units, so that the SI (Système International) has been introduced.

The introductory chapters on Vector Algebra are excellent. Clarity of exposition on what is at first sight a very abstract (and baffling) concept, is paramount, if such ideas as vectors are to be dealt with in a child's syllabus. No doubt limitations of space in trying to compress within two covers of a school book sufficient material to satisfy examination needs, prevents the author from introducing vector methods in the theoretical treatment of subsequent chapters. Your reviewer's one complaint is that there are insufficient worked examples on Bow's Notation, as this particular elegant technique does not always "sink in" with the first one or two model answers.

This book is heartily recommended to all J.R.N.S.S. readers, who have to contend with assisting their sons and daughters struggling with an "A" Level Applied Mathematics syllabus as it is in Applied Mathematics rather than in Pure, that assistance is needed.

W. E. Silver

NOTICE TO READERS

The Editor extends to all readers of the Journal a cordial invitation to contribute articles of R.N.S.S., naval or general scientific and technical interest.

Authors are requested particularly to note that as the Journal is in the Restricted category the printing of material within its pages does not constitute open publication and does not prejudice the subsequent use of the material in the Journal of a learned society or institution, or in the scientific and technical press.

Manuscript should be typewritten if possible, in double spacing and on one side of the paper only. It should include, in addition to the title, the name of the Author together with initials, degrees and department, establishment or ship. Pseudonyms are acceptable only in special circumstances. A convenient length is between 3,000 and 5,000 words, but other lengths are acceptable and no contribution would be debarred on this ground alone. Illustrations are in most cases a desirable addition. Photographs should be of good quality, glossy, unmounted and preferably between two and three times the size of the required final picture. Graphs and line drawings should be made on a similar large scale, with bold lines to permit reduction in block making. A recent photograph and biographical note of the Author(s) will also be welcomed.

Views and opinions expressed in the Journal are not necessarily endorsed either by the R.N.S.S. or by the Editor.

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